AFIT/GEE/CEV/92S-7

AN ANALYSIS OF THE POTENTIAL USE OF RED HORSE CAPABILITIES AND TRAINING ACTIVITIES TO PERFORM OR ACCELERATE AIR FORCE ENVIRONMENTAL CLEANUPS

THESIS

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THESIS

Presented to the Faculty of the School of Engineering

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Master of Science in Engineering and Environmental Management

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Abstract

There are more than 4,000 Air Force sites requiring cleanup and restoration due to hazardous waste contamination. The Air Force goal is to completely restore all sites by 2000. One method of achieving this ambitious goal is to use in-house capabilities.

This study examined the potential use of RED HORSE capabilities and training activities to assist with cleanup of contaminated sites. RED HORSE capabilities and training requirements were compared to the primary cleanup needs of the Air Force.

One finding of this study suggests cleanup of sites contaminated by volatile organic chemicals (VOCs) is the primary need of the Air Force. The findings also indicate that RED HORSE can not perform remediation work on uncontrolled hazardous waste sites due to a lack of training and protective equipment required by OSHA regulations.

This study suggests that if RED HORSE was provided with the required training and equipment, up to 30 technologies are within RED HORSE capabilities and offer high training benefits, and up to 39 would provide moderate or low training benefits.

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I. Introduction

General Issue

> President Bush wants to be known as the environmental president. Secretary of Defense Cheney wants the DOD to be the leader of the federal agencies in environmental compliance. Air Force Chief of Staff General McPeak wants the environmental program to be the bulwark of his administration. (49:2)

The desires expressed above and legal and moral concerns for the environment have driven the development of the Air Force environmental management program. This program is divided into past, present, and future areas of focus. The past includes cleanup; the present includes compliance; and the future includes prevention, planning, and protecting cultural and natural resources. Each area has its specific goal, with the cleanup goal being "Restore at least 10% of our hazardous waste sites annually with all sites completed by 2000" (25).

This thesis focused on the restoration goal and the potential use of RED HORSE to perform environmental cleanups. Col Nay, the Commander of the Air Force Civil Engineering Support Agency (formerly the Air Force Engineering and Service Center), believes the restoration goal is the most compelling, with more than 4,000 Air Force sites identified for cleanup as of August 1991 (30:4).

Specific Research Problem

RED HORSE Squadrons are the only self-sustaining Air Force Civil Engineering combat units. To maintain their combat-ready heavy construction and repair capability, RED HORSE (referring hereafter to all RED HORSE Squadrons) must carry out a comprehensive training program during peacetime. According to Air Force Regulation 93-9, the two primary objectives of the RED HORSE training program are to:

> a. Develop and maintain a highly skilled, mobile, self-sufficient Air Force combat engineering force capable of rapid response and independent operations to support contingency operations worldwide.
>
> b. Provide supplementary training to make sure that Air Force RED HORSE military personnel are able to perform direct combat support tasks including unique engineering capabilities maintained only by RED HORSE units. (7:6)

The specific research problem of this thesis was to determine the extent to which RED HORSE capabilities and training activities can be used to perform or accelerate Air Force environmental cleanups.

Investigative Questions

The following questions provided guidance and direction for this research effort.

1. What were the primary environmental cleanup needs of the Air Force?

2. What technologies have been successfully used in environmental cleanup activities?

3. What constraints restrict the use of RED HORSE to perform environmental cleanups?

4. Within delineated constraints, how can RED HORSE be used to satisfy Air Force cleanup requirements?

Scope and Limitations

While all factors relating to environmental cleanup deserve study, this research investigated cleanup strategies associated with only one class of contaminants. Initially, this study looked at the following site types: fire training areas, underground storage tanks, spill sites, landfills, surface impoundments, waste piles, above ground tanks, and enclosed structures; and narrowed them down to the most frequently occurring type for further investigation. Contaminant types were also investigated. This study is not a decision tool for choosing a cleanup technology for a given site. Instead, it provides a listing of strategies for one specific class of contaminants that has met RED HORSE capability, mission, legal, and training constraints. Only available technologies were considered; innovative and emerging technologies were defined but not investigated for consideration.

The Installation Restoration Program served as the primary database for this research. However, this study did not give special attention to sites on the National Priority List (NPL). Sites not associated with the IRP were not excluded from this study. Both controlled and uncontrolled hazardous waste sites were considered.

The study addressed only federal legal requirements. State and local regulations and laws were not addressed.

Determination of the availability of rental equipment (an option when RED HORSE has operating expertise but equipment is not within current inventory) was based on a sample of local vendors and therefore was not comprehensive. Costs associated with each technology were not considered. Potential benefits accruing to the AF by using RED HORSE to perform environmental cleanups were determined.

Definition of Terms

This research study is intended for two audiences. One is the base environmental manager in charge of remediation activities and the other is the RED HORSE project manager in charge of the construction team. In order for each of these groups to have a common language, the following definitions are presented. Throughout this research, definitions pertinent to each section are presented within that section. Definitions for each technology are presented in Appendix A.

Controlled hazardous waste site. A site contaminated by hazardous wastes that have been containerized, encapsulated, or treated in a manner that reduces the probability of their migrating from the site.

Environmental Cleanup. The process of rendering harmless a hazardous waste that has contaminated a medium by removing the hazardous waste or reducing or eliminating associated risks.

Hazardous Waste Site. Any site contaminated by a chemical that is an Environmental Protection Agency listed hazardous waste or exhibits hazardous waste characteristics of ignitability, corrosivity, reactivity, or toxicity.

Heavy Construction. Attribute associated with a large earth moving and paving capability.

Heavy Repair. Attribute associated with the ability to restore heavily damaged facilities, utilities, and pavements to serviceable condition.

Installation Restoration Program. The Air Force program to identify, investigate, clean up, and close out hazardous waste sites.

Mission. The primary purpose or objective of RED HORSE.

National Priority List. The worst sites identified by the Environmental Protection Agency (EPA) as needing cleanup under Superfund. The sites generally have at least one of the following: an issued health advisory recommending persons stay away; an EPA determination that the site poses a significant danger to public health; or an EPA decision to approach cleanup on-site as opposed to a removal action (13:179).

RED HORSE. An acronym for Rapid Engineer Deployable, Heavy Operational Repair Squadron, Engineer (7).

Technologies. The method, strategy or approach (including materials) used to remediate or clean sites.

Uncontrolled Hazardous Waste Site. These are sites contaminated by hazardous wastes that have the potential to migrate from the site or are not fully confined to the site boundary.

Overview

The methodology used to determine the viability of using RED HORSE to perform environmental cleanups is described in Chapter II. Specific cleanup requirements were determined by reviewing IRP cleanup needs. A comprehensive literature review identified potential cleanup Technologies. Technologies were evaluated to determine applicability to specified cleanup needs. A literature review developed the constraints affecting the use of RED HORSE, including capability, mission, legal, and training constraints. Capability was determined based on job skills and heavy repair/construction equipment availability. Mission constraints included actions inconsistent with Air Force Regulations and RED HORSE concept of operations. Legal constraints included a review of regulations concerning transportation of hazardous wastes on public roads, treatment permitting, and training and the use of monitoring devices, sampling instruments, and personal protective equipment. RED HORSE training constraints considered project duration, project diversity, and availability and use of equipment.

To set the foundation for the rest of this thesis, Chapter III provides a review and analysis of the primary clean up needs of the Air Force. Chapter III also identifies the treatment strategies according to the USEPA's Remedial Action Classification Scheme (38) that are evaluated within this study. A comprehensive literature review (Appendix A) provided a short definition of each potential remediation technology. The primary cleanup needs of the Air Force were then compared to the technologies for applicability.

Chapter IV provides a literature review of RED HORSE mission, capabilities, and training requirements. These requirements were then compared to the technologies previously determined to be applicable to the primary cleanup needs of the Air Force.

Legal constraints affecting the use of RED HORSE were then developed in Chapter V. These constraints were based upon federal regulations. Technologies that met the previous constraints were then compared to the legal constraints.

Chapter VI summarizes the constraints and their boundaries. Tables comparing the technologies to the identified constraints are developed. Chapter VI discusses some of the benefits and drawbacks of using RED HORSE for environmental cleanup activities. Recommendations for areas warranting follow-on study are presented.

II. Methodology

Overview

The research objectives were achieved primarily by collecting data from the literature. Data gaps identified during the literature review were filled using personal interviews, telephone surveys or mail (including electronic mail) surveys. As most of this research was exploratory in nature, personal interviews and telephone surveys were used.

The general approach used to answer each investigative question and ultimately the research question is discussed in the method of approach section.

Method of Approach

The first investigative question dealt with determining the primary remediation needs of the Air Force. The second question involved determination of the population of potential remediation technologies, techniques and/or strategies (hereafter referred to as technologies). The third question required determining constraints affecting use of RED HORSE. Finally, the last question looked at matching RED HORSE capabilities (within delineated constraints) to Air Force cleanup needs .

Determination of Remediation Requirements. The Air Force has a wide variety of environmental cleanup needs. These needs include remediation of fire pit training areas, landfills, fuel spills, solvent spills, firing ranges, underground storage tanks (USTs), crash sites, pesticide rinse areas, abandoned hazardous waste storage sites and a wide variety of other site types. Thousands of sites were characterized during the site identification phase of the Installation Restoration Program (IRP). Therefore, the first investigative question was answered based on a literature review of the frequency of IRP site types and contaminant types requiring remediation. Risks associated with site and contaminant types were also considered by looking at the Defense Priority Model rankings.

Remediation Technology Identification. Remediation technologies were identified by a literature review. The technologies of interest were limited to those which have been successfully used to clean or remediate a site (technologies currently participating in the EPA Superfund Innovative Technology Evaluation program were defined but not included for consideration). These technologies were then compared with the clean up requirements previously identified. Technologies that had previously been successfully demonstrated on sites similar to those of interest were classified as compatible technologies. Technologies not classified as compatible technologies were classified as incompatible technologies and were discarded from further consideration.

Constraint Identification. RED HORSE constraints were broken into the following four categories: capabilities, mission, legal, and training. Capabilities were determined by reviewing literature in the form of past projects, job skills, and equipment availability. Equipment was considered available if:

a. it was part of RED HORSE's table of allowances; or

b. could be obtained by local rental.

Technologies having equipment, training, and specialized skills or similar requirements unavailable to RED HORSE were eliminated from further consideration at this stage.

The RED HORSE mission was identified based on review of appropriate regulations, supporting pamphlets, and prior theses. Technologies requiring actions inconsistent with the RED HORSE mission were identified and classified as incompatible at this stage.

Legal constraints were identified at the federal level. The primary focus of this section was to determine legal constraints imposed by the Environmental Protection Agency (EPA), Occupational, Safety and Health Administration (OSHA), and Air Force regulations. Other areas including contracting restrictions were identified. Legal constraints were determined by reviewing the Code of Federal Regulations (CFRs) and Federal Acquisition Regulations (FARs).

Constraints identified by the literature review were evaluated to determine the magnitude of their effect. On the basis of this evaluation, constraints were classified as level one, two, or three. Level one constraints were deemed trivial or minor. These included constraints that could be overcome by uncomplicated or routine actions such as notifications of proposed actions. Level two constraints were those requiring a significant effort or specialized knowledge to overcome but were within the capability of the Air Force to achieve. Level three constraints were those requiring intensive efforts to overcome. These included major policy changes at or above the agency level (EPA, DOD) or congressional action.

Legal constraints were compared with technologies and identified as those which were (1) routine and inconsequential, (2) required significant actions or changes but were within the capabilities of the Air Force to effect, (3) those requiring actions beyond the capability of the Air Force to effect.

Comparison of Constraints to Requirements. Technologies which successfully filtered through the above steps are considered technologies within RED HORSE capabilities and mission. Incompatible technologies are categorized according to rejection criteria.

III. Results: Air Force Primary Cleanup Needs

Overview

The purpose of this research was to determine to what extent RED HORSE could be used to perform or accelerate Air Force environmental cleanups. This chapter answers the first two investigative questions which involved identification of the primary environmental cleanup needs of the Air Force and environmental cleanup technologies.

A review was performed across the Air Force to determine the types of sites requiring cleanup. The compounds most frequently contaminating sites were also determined. The Air Force Installation Restoration Program (IRP) served as the database for this review.

Sites posing the greatest risk were determined based on Defense Priority Model (DPM) scores. These sites were evaluated to identify the class of contaminants posing the greatest risk.

The technologies used to perform environmental remediations were identified. The primary cleanup needs of the Air Force were then compared to this list of technologies.

Review of Installation Restoration Program.

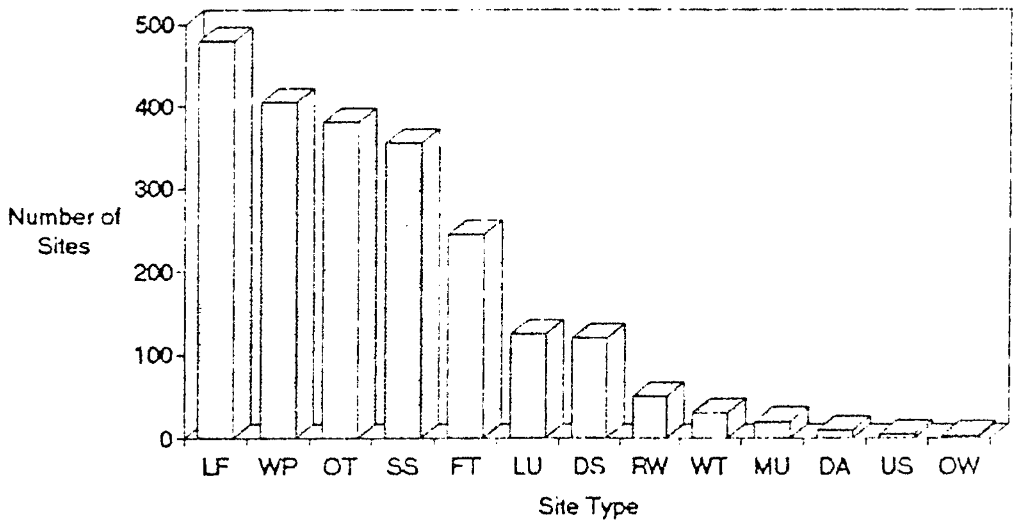
The Installation Restoration Program (IRP) is a Department of Defense (DOD) program designed to clean up areas contaminated by past activities. Many of the contaminated sites resulted from operations that were in full compliance with the law and regulations of the time. Sites include petroleum and chemical spill sites that went unnoticed, were only partially cleaned, or not cleaned at all due to requirements of the time (51:1). The IRP applies only to past activities; not areas contaminated by current operations. However, the clean up strategies investigated in this research cross the boundaries between past and present.

The IRP is similar to the Environmental Protection Agency's Superfund Program. Superfund was established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and further amended by the Superfund Amendments and Reauthorization Act (SARA). SARA established the Defense Environmental Restoration Program (DERP) and the Defense Environmental Restoration Account (DERA). IRP actions should be accomplished using DERA funding and are not eligible for Superfund program funding. The IRP goes beyond Superfund and considers all DOD sites, whereas Superfund considers only the worst uncontrolled hazardous waste sites.

The IRP program is a dynamic and growing program. In August 1990, the Air Force IRP contained more than 2000 hazardous waste sites distributed among 196 installations within and outside the United States (17:873). The number of sites increased to 4323 as of 1 June 1992 (5).

The sites can be grouped into at least 13 categories. Figure 1 illustrates the frequency of occurrence of the sites within the various categories as of 1990.

The typical Air Force installation had an average of 12 sites in 1990 (17:873). The largest number of sites on an installation was 132. Figure 1 indicates that sites falling into the landfill category are the most common as of 1990.



Legend:	LF	Landfill	DS	Drum Storage Area
	WP	Waste Disposal Lagoon/Pit	RW	Radioactive Waste Site
			WT	Waste Treatment Facility
	OT	Other	MU	Munition Disposal
	SS	Spill Site/Area	DA	Discharge Area or Surface Drainage
	FT	Fire Protection Training Area/Pit	US	Underground Storage Tank or Pipeline
	LU	Leaking Underground Storage Tank/Pipes	OW	Oil/Water Separator

Figure 1. Air Force IRP Program Frequency of Site Types (17:874)

After the discovery of a hazardous waste site, the next task is to determine the nature and extent of contamination. The contaminated media can include surface water, groundwater, process water, soils, air, facilities, and equipment. The two primary sampling methods used at Air Force IRP sites are monitoring wells and boreholes (17:874).

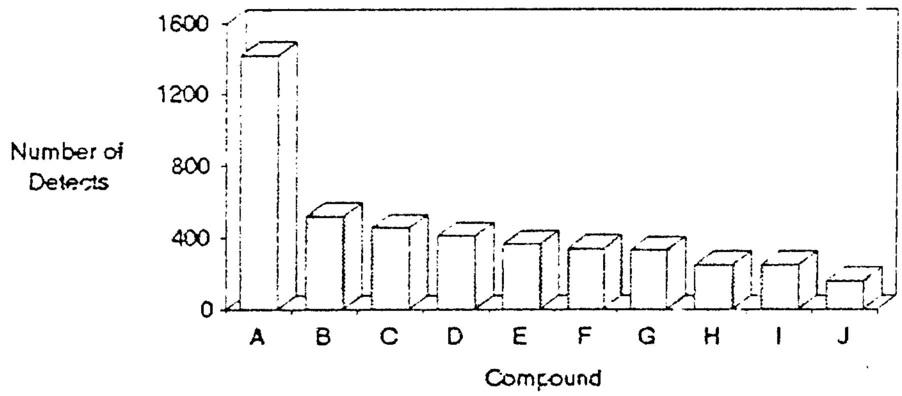
Determining the types of contamination present at a site can be difficult. Part of this difficulty is caused by the detection limits of today's analytical laboratories. Identification and quantification of numerous compounds at or below the part per billion (micrograms per liter) level are routine. Many compounds considered contaminants at certain sites are naturally occurring at others.

A primary medium of concern is groundwater. Groundwater supplies approximately one-third of the United State's drinking water, and in the western part of the country it supplies closer to half. According to Masters, "Once contaminated, groundwater is difficult, if not impossible, to restore" (24:147).

Figure 2 shows a listing of the 10 most common organic compounds detected in groundwater across the Air Force Installation Restoration Program. The frequency is based on the total number of sampling locations. It is not surprising that the most common organic contaminants found on Air Force installations are those associated with solvents and fuels which are a result of activities related to airplane maintenance and fuels storage/handling (17:874). As Figure 2 shows, trichloroethylene (TCE) is the most common contaminant detected. Toluene and benzene are also commonly detected. Toluene is the most frequently detected contaminant found at fire training areas (17:875).

Soil is also a medium of concern. Contaminants in soil can migrate from a site by a number of mechanisms. The primary mechanisms are volatilization, adherence to wind-blown dust particles, and leaching.

Data from the Installation Restoration Program Information Management System (IRPIMS) show that the most commonly detected organic compounds in soil are petroleum hydrocarbons. Figure 3 shows the 10



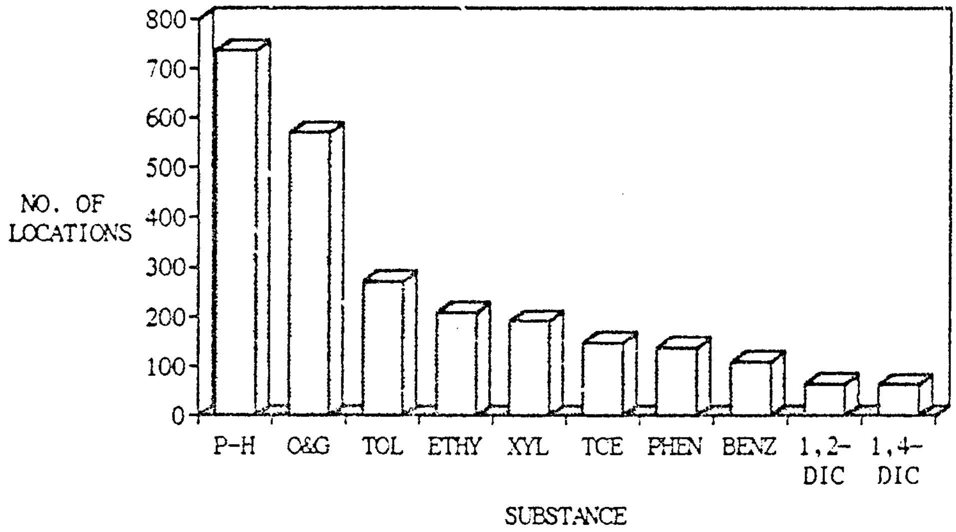
Legend:	A	Trichloroethylene (TCE)
	B	Toluene
	C	Benzene
	D	Phenolics
	E	Tetrachloroethylene (PCE)
	F	Ethylbenzene
	G	1,1,1-Trichloroethane (TCA)
	H	trans-1,2-Dichloroethene (DCE)
	I	1,4-Dichlorobenzene
	J	1,1-Dichloroethane (DCA)

Figure 2. Most Common Organic Compounds Detected in Groundwater (17:874)

most common organic substances that have been detected in soils at Air Force IRP sites.

Defense Priority Model.

The Defense Priority Model (DPM) is a system that scores sites numerically on a scale of 0 to 100. A higher score is associated with increased risk. The model is used to assist with prioritization of IRP remediation activities and budgeting requirements. It considers the contaminant pathway, toxicity of the contaminant, and receptors.



Legend:

P-H	Petroleum Hydrocarbons	O&G	Oil & Grease, Total Rec
TOL	Toluene	ETHY	Ethylbenzene
XYL	Xylenes, Total	TCE	Tricloroethylene
PHEN	Phenolics, Total Recoverable	BENZ	Benzene
1,2-Dic	1,2-Dichlorobenzene	1,4-Dic	1,4-Dichlorobenzene

Figure 3. Ten Most Common Organic Chemicals Detected In Soil Across The USAF Installation Restoration Program (IRP) (16)

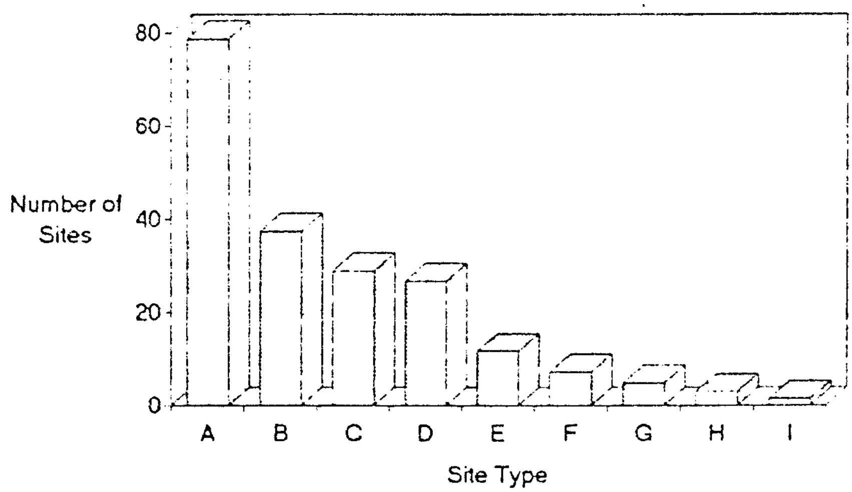
However, the DPM is not the only consideration in establishing site priorities. Other considerations include mission impact, community concerns, regulatory considerations, and program efficiencies (51:120). The DPM is a tool that provides the decision maker with a rational methodology in establishing priorities for IRP site cleanup. Thus, it is used to help ensure the worst sites are cleaned up first and that the best use is made of limited resources. Figure 4 shows the number of sites scored by site type for the Air Force in fiscal years 1991 and 1992.

As Figure 4 shows, the largest number of sites scored in FY 91 and FY 92 are spill sites. Figure 5 illustrates the frequency of pollutants found at the sites that were scored. The most frequent pollutants found are benzene and toluene, which are associated with fuels. Figure 5 presents only the top ten most frequently found pollutants, not necessarily the most hazardous.

There were 18 Air Force sites with scores exceeding 40.0 for FY 92. These scores were determined using the 1992 version of the DPM. The sites consist of seven landfills, five spills, three underground storage tanks (USTs) and three unidentified site types (18).

Complete DPM data files were available for seven of these 18 sites. The seven sites consisted of four landfills, two spill sites and two UST sites. These sites were rescored using the 1993 version of the DPM. DPM scores were also determined for each site considering organic contamination and inorganic contamination separately. Scores generated for each site are shown in Table 1.

Discussion. Prioritization for Air Force environmental cleanup needs occurs at four levels. These are the Defense Priority System, through the use of the Defense Priority Model, Headquarters USAF project priority codes, major command priority, and installation priorities (51:73-76). Each level contains a few different factors not considered in other levels. For this study, determination of primary clean up needs was based on the total Air Force IRP Program. Site type



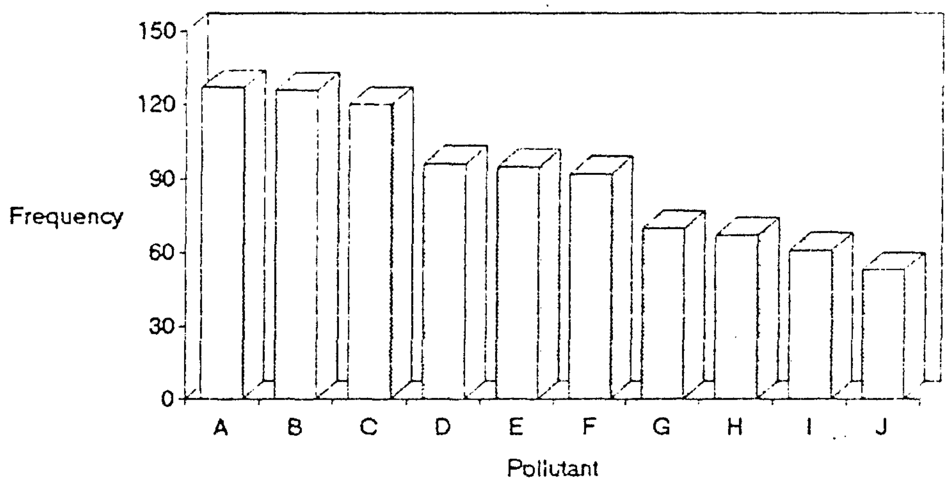
Legend:	A	Spill Sites		E	Surface Impoundment
	B	Landfills		F	Groundwater Contaminant
	C	Underground Storage Tanks		G	Waste Piles
				H	Above Ground Tanks
	D	Fire Training Area		I	Enclosed Structure

Figure 4. FY 91 & FY 92 DPM Hazardous Waste Site Scoring (11:14)

and contaminant type(s) were considered. Other priorities were not considered by this study.

Based on Figure 1 (Air Force IRP Program Frequency of Site Types) the most frequent type of IRP site is a landfill. A confounding factor, however, is that prior to 1990, USTs were specifically excluded from the IRP program. Therefore, UST sites may be underrepresented in Figure 1. This factor, along with finding previously overlooked sites, might account for the doubling of the number of sites from 1990 to 1992.

Figure 4 (FY 91 & 92 DPM Hazardous Waste Site Scoring) indicates that spill sites were scored more frequently than any other site types



Legend:				
	A	Benzene	F	Trichloroethylene
	B	Toluene	G	Arsenic
	C	Lead	H	Tetrachloroethylene
	D	Ethyl Benzene	I	Methylene Chloride
	E	Xylene	J	Cadmium

Figure 5. FY 92 DPM Pollutant Frequency Scoring (11:12)

TABLE 1

DEFENSE PRIORITY MODEL SCORES

Location	Site Type	1992	1993	Organic	Inorganic
Wright Patterson	Landfills 8&10	60.7	63.8	62.2	59.9
Wright Patterson	Landfills 11&12	51.1	52.0	34.6	48.7
Kelly	Landfill D-2	49.5	51.6	50.9	35.5
AF Academy	Landfill 2	49.3	45.2	42.4	44.3
Tinker	Groundwater[a]	44.2	23.5	23.5	0.0
Kelly	SS03 Spill	48.0	47.5	42.5	37.1
Columbus	Spill Site 5	41.7	42.6	42.6	9.5

a. USTs were source of contamination.

for FY 91 and 92. Landfill sites barely edge out UST sites and fire training areas as the second most frequently scored.

The primary type of contamination at spill sites, fire training pits, and underground storage tanks (USTs) is organic contamination. This is expected as fuels and most solvents are organic compounds. Organic contamination at these sites also belongs to the class of organic compounds known as volatile organic compounds (VOCs). On the basis of the above, it is logical to consider spill sites, fire training pits and USTs as a similar category. Thus, sites contaminated with VOCs would be the more frequently occurring.

The most frequently scored contaminants for FY 92 were organics. The two most frequently (and seven of the 10 most frequently) detected contaminants in groundwater were also organics. This supports the assertion by Hunter that most Air Force contamination is related to fuels and solvents and thus is organic in nature (17:874).

It could be argued that determining the primary restoration needs of the Air Force solely upon frequency of a type of contamination is insufficient. This argument can be advanced with credibility given that the type of contamination found is directly dependent upon the type or types of analyses performed. For example, inorganic contaminants would not be identified if only a volatile organic scan is performed (of course, organic contamination would not be detected if only an analysis for metals was performed).

A second factor to consider is that inorganics such as aluminum, silicon, iron, magnesium, calcium and others are naturally occurring.

Thus, any soil or groundwater analysis for inorganics would likely show the above mentioned compounds present at some trace level.

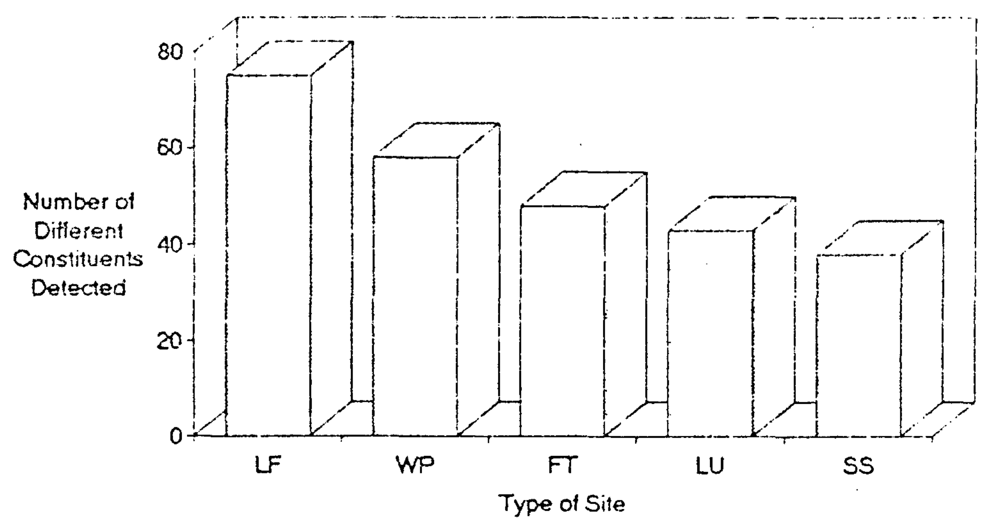
The concern regarding the presence of inorganic contamination at trace levels is addressed by reviewing the DPM scores in Table 1. For six of the seven sites scored, inorganic contamination was found. No inorganic contaminants were identified in the data file for the Tinker site. The absence of inorganic data could be due to any number of factors including not being present above background levels, or failure to run the required tests.

DPM scores for the four landfills were evenly mixed, with two sites showing organic contamination to be the primary problem and two sites showing inorganic contamination to be the primary problem. Scores for the UST site and two spill sites were more definitive, with organic contamination producing a higher score (and therefore indicating higher priority or risk associated with it) than inorganic contamination in all three cases.

The sample size of seven sites is not statistically significant given the population size is more than 4000. In addition, the sample was not selected at random. These factors preclude any statistical inferences to other Air Force sites. However, the data suggest that organic contamination should be of higher priority than inorganic contamination.

The primary problem appears to be organic contamination. This conclusion is supported by the fact that most contamination at spill sites, fire training pits, and USTs is due to organic pollutants. The two most frequent and seven of the 10 most frequent contaminants detected in groundwater were organics. Consideration of organic contaminants separate from inorganic contaminants showed that organic contamination produced higher DPM scores in five of the seven cases. The highest of the separate DPM scores was also due to organic contamination.

A large number of different organic compounds are found at hazardous waste sites. Figure 6 illustrates the number of organic compounds detected at selected site types.



Legend: LF Landfill
WP Waste Lagoon, Weathering Pit
FT Fire Training Area
LU Underground Storage Tank
SS Spill Site

Figure 6. Variety of Organic Constituents Detected in Groundwater at Selected Site Types (17:875)

With the exception of the many phenolic compounds, (and possibly 1,2-dichlorobenzene) the organic contaminants shown in figure 2 belong to the class of organics known as volatile organic compounds (VOCs).

A comparison of Figure 2 (Most Common Organic Compounds Detected in Groundwater) and Figure 5 (FY 92 DPM Pollutant Frequency Scoring) shows that tricholoroethylene (TCE), benzene, and toluene are the most frequent contaminants found at Air Force IRP sites. Each of these belongs to the class of organic compounds known as volatile organics. This suggests the strong likelihood that VOCs are a primary cause of contamination at Air Force IRP sites.

For the remainder of this research project, the primary remediation requirement of the Air Force is considered to be the clean up of VOCs.

Technology Identification

Technologies capable of remediating VOC contaminated sites were determined by first identifying the universe of potential remediation technologies. These technologies were then investigated to determine their potential application to sites contaminated with VOCs. The technologies were sorted into two categories, those successfully applied to organics and those that are innovative, emerging, or not applicable to treatment of VOCs.

The universe of potential remediation technologies considered in this study are shown in Table 2 (Potential Hazardous Waste Cleanup Technologies). Technologies capable of being applied to VOCs are identified in the tables presented in chapter VI.

TABLE 2

POTENTIAL HAZARDOUS WASTE SITE CLEANUP TECHNOLOGIES (38:3-9)

I. Surface Water Strategies

   A. Containment
      1. Cofferdams
      2. Floating Cover
      3. Silt Curtain & Booms

   B. Diversion
      1. Dikes & Berms
      2. Terraces & Benches
      3. Levees
      4. Floodwalls

   C. Collection
      1. Ditches, Trenches, & Diversions
      2. Chutes & Downpipes
      3. Seepage Basins & Ponds

II. Ground Water Strategies

   A. Containment
      1. Slurry Walls
         a. Soil/Cement-Bentonite
         b. Vibrating Beam
      2. Sheet Piling
      3. Grout Injection
      4. Grout Curtain
      5. Bottom Sealing
      6. Controlled Pumping

   B. Collection
      1. Pumping
         a. Well Points
         b. Withdrawal Wells
         c. Deep Wells
      2. Drains
         a. Pipe Drains
         b. Gravel Drains
      3. Pure Compound Recovery
         a. Direct Pumping
         b. Mechanical Skimming
         c. Oil/Water Separator
         d. Interceptor Trench

   C. In-Situ Treatment
      1. Bioreclamation

TABLE 2 (CONT)

POTENTIAL HAZARDOUS WASTE SITE CLEANUP TECHNOLOGIES (38:3-9)

2. Subsurface Chemical Injection
3. Permeable Barriers

III. Aqueous Waste Strategies

A. Treatment
1. Physical Treatment
a. Flocculation
b. Sedimentation
c. Filtration
d. Skimming
e. Dissolved Air Flotation
f. Oil/Water Separator
g. Air Stripping
h. Steam Stripping
i. Distillation
k. Ion Exchange
j. Evaporation
l. Carbon Adsorption
m. Resin Adsorption
n. Biosorption
o. Reverse Osmosis
p. Ultrafiltration
q. Solvent Extraction
r. Freeze-crystallization
2. Chemical Treatment
a. Precipitation
b. Oxidation
c. Reduction
e. Hydrolysis
f. Electrolysis
g. UV Photolysis
h. Ozonation
i. Wet Air Oxidation
j. Super Critical Wet Air Oxidation
k. Dehalogenation
3. Biological Treatment
a. Lagoons
i. Aerated Lagoon
ii. Facultative Lagoon
iii. Stabilization Pond
iv. Algal Pond
b. Suspended Growth Processes
i. Activated Sludge
ii. Sequencing Batch Reactor

TABLE 2 (CONT)

POTENTIAL HAZARDOUS WASTE SITE CLEANUP TECHNOLOGIES (38:3-9)

- iii. Oxidation Ditch
- iv. Powdered Activated Carbon Treatment

c. Attached Growth Processes
- i. Trickling Filter
- ii. Rotating Biological Contactor (RBC)
- iii. Aerated Biofilter
- iv. Anaerobic Biofilter
- v. Fluidized Bed Reactor

d. Land Treatment
- i. Overland Flow
- ii. Spray Irrigation
- iii. Infiltration Basin

4. Thermal Destruction
   - a. Liquid Injector Incineration
   - b. Pyrolysis
   - c. Plasma Arc Pyrolysis
   - d. Industrial Boilers
   - e. Cement & Lime Kilns

B. Disposal
1. Discharge to Surface Water
2. Discharge to Sewer System/POTW
3. Land Application
4. Deep Well Injection
5. Surface Impoundment
6. RCRA TSDF

IV. Sludge/Sediment Strategies

A. Collection
1. Dredging
2. Vacuum Loading

B. In-Situ Treatment
1. Drying
2. Chemical Fixation

C. Ex-Situ Treatment
1. Dewatering
   - a. Gravity Thickening
   - b. Air Flotation Thickening
   - c. Vacuum Filtration
   - d. Filter Press
   - e. Centrifugation
   - f. Carver-Greenfield Process

TABLE 2 (CONT)

POTENTIAL HAZARDOUS WASTE SITE CLEANUP TECHNOLOGIES (38:3-9)

D. Storage
   1. Lagoons
   2. Surface Impoundments

E. Disposal
   1. POTW
   2. RCRA TSDF
   3. Off-Site Landfill
   4. On-Site Landfill
   5. Surface Impoundment

V. Soil Strategies

A. In-Situ Treatment
   1. Soil Flushing
   2. Vacuum Extraction
   3. Chemical Fixation
   4. Vitrification
   5. Land Farming

B. Collection
   1. Excavation
   2. Solids Handling
      a. Screening
      b. Scalping

C. Ex-Situ Treatment
   1. Soil Washing
   2. Thermal Desorption
   3. Chemical Fixation
   4. Biological Treatment
      a. Slurry Reactor
      b. Land Farming
      c. Composting
   5. Solvent Extraction
   6. Wet Air Oxidation
   7. Thermal Destruction
      a. Rotary Kiln Incinerator
      b. Fluidized Bed Incinerator
      c. Circulating Bed Combuster
      d. Multiple Hearth Incinerator
      e. Molten Salt Combustion
      f. Pyrolysis
      g. Plasma Arc Pyrolysis
      h. Infrared Incineration
      i. Industrial Boilers
      j. Cement & Lime Kilns

TABLE 2 (CONT)

POTENTIAL HAZARDOUS WASTE SITE CLEANUP TECHNOLOGIES (38:3-9)

D. Storage
   1. Waste Piles

E. Disposal
   1. Off-Site Landfill
   2. On-Site Landfill
   3. Surface Impoundment
   4. Mines & Salt Domes
   5. Storage Mounds

VI. Gas Control Strategies

A. Collection
   1. Passive Vents
   2. Gas Extraction Wells
   3. Air Injection Wells
   4. Air/Water Separator

B. Treatment
   1. Gas Phase Carbon Adsorption
   2. Catalytic Oxidation
   3. Vapor Combustion
   4. Flaring

VII. Drum & Debris Control Actions

A. Drum Removal

VIII. General Site Controls

A. Grading

B. Dust Control

C. Capping
   1. Soil
   2. Asphalt
   3. Concrete

D. Revegetation

IV. RED HORSE

Mission

This section is a review of the RED HORSE mission and training project requirements. The mission is further defined by a discussion of required unit characteristics and capabilities, personnel, and heavy construction equipment.

RED HORSE squadrons were first organized in 1965 as an Air Force response to the buildup requirements in Vietnam. At that time heavy bomb damage repair, disaster recovery, and major installation upgrade were beyond the capabilities of the Base Civil Engineer units. To support Air Force requirements, RED HORSE was formed to provide a mobile civil engineering unit, self-sufficient, and organic to the Air Force. That is, RED HORSE squadrons must be manned, trained, and equipped to perform heavy repairs and upgrades to airfields and facilities and to support weapons systems deployed to a theater of operations.

The fundamental mission of all RED HORSE units is basically as follows:

> A RED HORSE squadron performs heavy damage repair required for recovery of critical Air Force facilities and utility systems required for aircraft launch and recovery that have been subjected to enemy attack or to natural disaster; accomplishes required engineering support necessary for beddown of weapons systems, and the installation of critical utility and support systems required to initiate and sustain operations, especially in austere, bare base environments; provides, in peacetime, an engineering response force that can support special operations such as an aircraft crash or a nuclear accident recovery in remote areas or operating locations required by Joint Chiefs of Staff missions; and is manned, equipped and trained to conduct heavy engineering operations as independent self-sustaining units (with resupply of consumables) in remote hostile locations. The primary objectives

of the RED HORSE program are to develop and maintain a highly skilled, mobile, self-sufficient Air Force combat engineering force capable of rapid response and independent operations to support contingency operations worldwide; provide supplementary training to make sure that Air Force RED HORSE military personnel are able to perform direct combat support tasks including unique engineering capabilities maintained only by RED HORSE squadrons and develop and maintain Air National Guard (ANG) and United States Air Force Reserve (USAFR) RED HORSE forces for direct combat support (4:10-11).

Characteristics and Capabilities

To meet the important goals mentioned in the above mission statement, the Air Force Civil Engineering Support Agency has published required characteristics and capabilities of RED HORSE squadrons. Those characteristics and capabilities that can arguably be used in hazardous waste site cleanups are shown in Table 3 and further defined in Appendix B.

TABLE 3

REQUIRED CHARACTERISTICS AND CAPABILITIES OF RED HORSE SQUADRONS (15)

Engineering Capabilities	
Concrete Operations	Material Testing
Quarry Operations	Water Well Drilling
Mobile Facility Assets	Fuel Systems
Facility Hardening	Utility System Repair
Force Beddown	Heavy Earthwork
Roads	Power Generation Plants
Command and Control	Engineering Design
Unit Characteristics	
Disaster Preparedness	Medical Support
Firefighting	Explosive Ordnance Reconnaissance
Vehicle Maintenance	Flexibility
Contracting	Mobility

Organization and Manning

RED HORSE units have been sized accordingly to meet planned mission requirements. A typical squadron configuration has 17 officer/engineers and 387 enlisted personnel. Figure 7 shows a typical peacetime organizational structure.

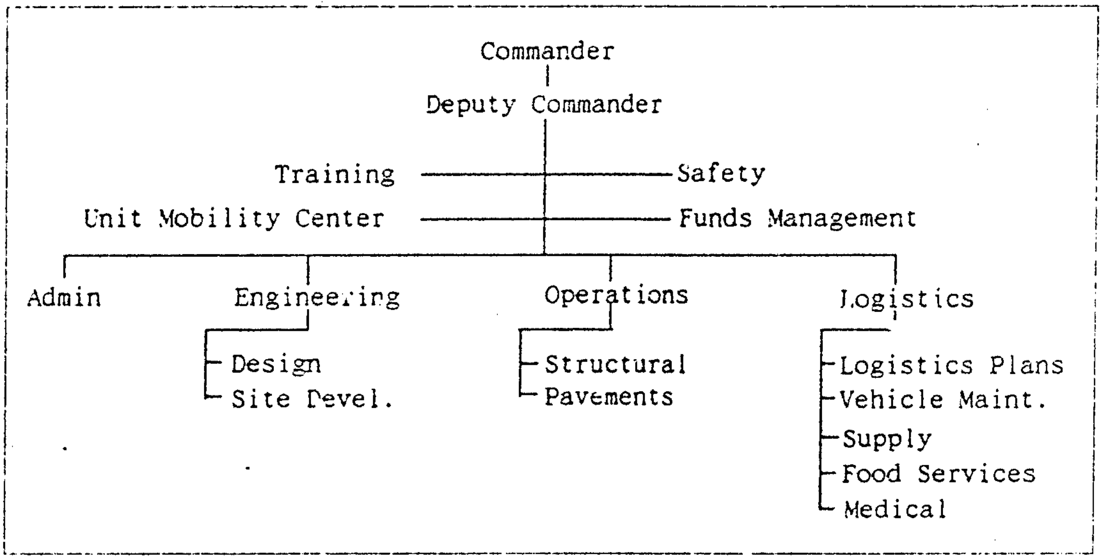


Figure 7. Peacetime Organizational Structure (7)

Within this organization many of the same skills found in a Base Civil Engineer squadron are found in RED HORSE's engineering and operations branches. Engineering design has civil, electrical, and mechanical engineers. The Site Development section has draftsmen and surveyors, along with construction inspection and material testing capabilities. The material testing capabilities include concrete, asphalt, and basic soils testing such as sieve analysis, atterburg limits, moisture density relationships, and compaction requirements. The Structural section of the Operations branch has carpenters, electricians, plumbers, metal workers, and environmental skills (water/waste). The Pavements section is at the heart of RED HORSE with the heavy equipment operators, pavement technicians, and well drillers.

What really makes RED HORSE self-sufficient is the logistics branch. While a Base Civil Engineer unit will require these services from other base squadrons, RED HORSE has an in-house capability. What is not shown in the organization chart, but is an important player if RED HORSE is to do environmental cleanup, is the Disaster Preparedness section which was recently added.

Heavy Equipment

A primary distinction between RED HORSE and Base Civil Engineer units is the special capabilities of RED HORSE as described in Appendix B. To support these capabilities and retain their self-sufficiency, RED HORSE retains vehicle and heavy construction equipment sets. While not all units have the same type, quantity, or condition of operating equipment, Table 4 gives a general breakdown of heavy construction equipment available. However, lack of a specific piece of equipment usually does not stop a job, as rental equipment is sometimes used.

In contrast to the mission of Base Civil Engineer squadrons, RED HORSE was formed specifically to meet wartime needs. As such, its composition is based on wartime requirements, and it is not assigned to an air base to perform peacetime operations and maintenance taskings. Its primary mission in peacetime is to train for wartime and as previously mentioned in the Specific Research Problem, it must carry out

TABLE 4

RED HORSE HEAVY CONSTRUCTION EQUIPMENT
(* items found only at 820th RED HORSE) (7)

Excavator, Truck Mounted (Gradall)	
Loaders and Other Excavators	
Loader, Scoop W/Backhoe	Loader, Scoop 2-1/2CY W/Q.C.
Loader, Scoop Full Track 2-1/2CY	Trencher, Self-Propelled Rubber Tired
Loader, Scoop 4CY	
Transportation of Excavation	
Truck, Dump 8CY 6x4	Truck, Dump 14CY 6x4
Truck, Dump 20 Ton Rock *	
Tractors and Dozers	
Tractor, Full Track Size T-7	Tractor, Full Track Size T-9
Tractor, Full Track Size T-4	
Scrapers	
Scraper, 18CY	
Compaction	
Roller, Vibrating Self-Propelled	Roller, Towed 13 Tired
Roller MTZ 15 Ton Pnuematic Tired	
Graders and Finishing	
Grader, Road Size 5	Grader, Road Size 2
Rock Excavation	
Conveyor, Material Aggregate Portable *	Crushing & Screen Plant 150 TPH Trailer Mounted *
Rock Drill, Crawler Mounted *	
Concrete Equipment	
Concrete Mobile 8CY	Mixer, Concrete Trailer Mtd 6CF
Bituminous Equipment	
Distributor, Asphalt Truck 800 Gal	Paving Machine, Asphalt Rubber Tired
Other Miscellaneous Equipment	
Cleaner, Vacuum Multi-Purpose	Distributor Truck, Water 1500 Gal
Distrib. Trailer, Water 5000 Gal	Mixer, Roto Tiller Self-Propelled
Sweeper, Towed Rotary Broom	Tractor, Farm
Trailer, Water 400 Gal	Truck, Fuel 1200 Gal
Truck, Telephone Line Maint/Const	Forklift, 10K Adverse Terrain
Well Drilling Machine	

a comprehensive training program to maintain combat-ready heavy construction and repair capability.

Limitations

RED HORSE capabilities are primarily constrained by manpower, and technical expertise. Jobs requiring many manhours of a specific type of skilled labor might be beyond RED HORSE's capabilities due to a lack of skilled craftsmen. Currently, RED HORSE would have difficulties with large masonry projects due to a lack of skilled masons (40). RED HORSE would also have difficulties with complex electrical or mechanical projects as RED HORSE engineers are only one deep in these areas (40).

More complex projects can be accomplished if the work involves installation of pre-packaged or prefabricated items and a manufacture's representative is available for onsite consultation. However, even with assistance from a manufacturer's representative, many complex jobs would be beyond RED HORSE's capability to complete.

Equipment limitations are present to a limited extent but are not critical. Heavy construction and repair equipment not owned by RED HORSE was found to be available by local rental (50). Deep well drilling equipment and special technical equipment like organic vapor analyzers and gas flow meters were not available from the local rental companies surveyed (50;21). However, discussions with RED HORSE personnel indicated that obtaining rental equipment or a subcontractor capable of providing a specialized service was not usually a problem (40).

Requirements of RED HORSE Training Projects

Preferred training projects are those presenting RED HORSE with the opportunity to utilize a diverse variety of their skills. All peacetime projects are considered training projects and must be treated as such according to Air Force Regulations and guidance. Training projects are picked that have activities similar to bomb damage repair, airfield construction, beddown operations, utility system installation, well drilling, runway repair with matting, vehicle maintenance under field conditions, barrier installation and others.

The list of activities above indicate that RED HORSE was designed to have the capacity for more than just construction and heavy repair.

Projects classified as RED HORSE training projects must meet the following requirements:

a. Add to unit proficiency and capability so they are similar to what the unit might reasonably be expected to accomplish during contingencies. Projects justified solely on the basis of economic benefit are not suitable.
b. Afford significant opportunity to enhance specific civil engineering skills of individual members of the unit working on the project and in equal part enhance the management, technical, and command skill of the unit.
c. Not conflict with the DOD policy of relying on the private enterprise system for products and services. Training projects should not compete with the types of work generally done by local contractors. A valid use may be when there is no contract capability in the local area, when there is a labor strike that would seriously impair the Air Force mission, when contractors are so involved in civilian contracts that there are no responses to an Air Force invitation for bids, or when security clearance requirements make contractor accomplishment infeasible. In addition, any project proposed within the US for RED HORSE accomplishment with a total cost funded and unfunded over $500,000 must be coordinated in advance with the Assistant Secretary of Defense (Manpower, Installation and Logistics) according to DODD 1135.2.
d. Should not have a mission sensitive beneficial occupancy date. RED HORSE is subject to no-notice, rapid deployment to support contingency and natural disaster requirements that would leave the project partially completed.

e. Be approved according to established project approval requirements of AFR 86-1. (7:31)

Summary

RED HORSE is the equivalent of a medium sized construction company. Specific achievements are not listed as RED HORSE is capable of most any type of general construction or repair work. Work requiring specialized expertise not identified previously is considered unaccomplishable.

V. Federal Regulation Review and Analysis

It is recognized that remediation of a hazardous waste site is a challenge. In order to meet the goals of the remedial action adequately, RED HORSE must possess technical competence, awareness of the regulatory basis for the remediation, and an ability for rigorous management. This section delineates the legal constraints that RED HORSE must overcome in order to become that competent contractor and provide a safe and complete hazardous waste site cleanup.

The primary purpose of remediation of sites contaminated by hazardous wastes is to reduce or prevent potentially adverse exposures. Similar occupational hazards are present at both hazardous and nonhazardous waste sites, though hazardous waste sites carry the potential for exposure to hazardous chemicals. For this reason, and because it is anticipated that compliance with safety and health regulations will be particularly problematic, legal constraints regarding safety, health, and potential exposure of RED HORSE personnel are developed in detail.

Requirements for Transportation of Hazardous Wastes

Transportation of hazardous wastes on-site (defined as within the facility boundaries) is not regulated (9:145). EPA recommends and encourages on-site remedial actions. However, when disposal of the waste on the premises of the waste generator is neither feasible nor desired, site closure must be accomplished through off-site remedies.

The most common off-site remedial actions leading to transportation of hazardous wastes are:

- Relocation of the waste to a secure landfill.
- Removal of the waste to an off-site treatment facility for detoxification.
- Incineration, with correct disposition of the residue.
- Reclamation and reuse of the waste, as when solvents are recycled. (32:364)

The transportation of hazardous waste is regulated by both the Hazardous Materials Transportation Act (HMTA) and the Resource Conservation and Recovery Act (RCRA). The Department of Transportation (DOT) is the primary regulatory agency for hazardous materials transport. RCRA required the EPA to initiate a cradle to grave tracking of hazardous wastes and to closely coordinate with DOT concerning manifest system, worker training, and management of environmental releases. Thus, the transporter must comply with regulations under both 40 CFR Part 263 (RCRA) and 49 CFR (HMTA) (2:311).

Any RED HORSE person engaged in the off-site transportation of hazardous waste by highway is considered a transporter. The requirements for the transporter/carrier under RCRA and HMTA are:

1. Notify EPA and obtain ID number.
2. Verify that shipment is properly identified, packaged, marked, labeled, and not leaking.
3. Apply appropriate placards.
4. Comply with the manifest requirements.
5. Comply with record keeping and reporting.
6. Take appropriate action (including cleanup) in the event of a release/spill.
7. Comply with DOT incident reporting rules. (47:83)

The two most difficult items above to overcome for RED HORSE personnel to become transporters of hazardous waste are item number one (permitting) and item number six (spill response). The permit process (under RCRA) requires application through the EPA Administrator (9:146). Obtaining a permit is a time consuming process. Also, although not mandatory under requirements of RCRA, many states use a licensing system. The licensing requirements concerning operator training, tariffs, routing, insurance coverage, handling of wastes, etc. may vary from state to state (27:90).

RCRA requires the transporter to take immediate action in the case of a discharge during transportation. Additionally, the transporter is responsible for cleaning up any discharge or taking approved appropriate action (9:148).

Specific training concerning hazardous material incident response is a must. The HMTA requires the carrier to receive within his training program instructions on the properties and potential hazards of the particular material being transported (37:847).

Most other transporter requirements of record keeping, manifesting, labeling, etc. can be learned and accomplished by RED HORSE personnel. These are activities similar to current operations. However, RED HORSE dump trucks are currently not configured for the transportation of hazardous waste. To comply with correct packaging of hazardous waste, the dump trucks must be fitted with gaskets for leak protection on the rear doors. This can also be accomplished with waterproof caulk or other waterproof material. After this, a liner is placed inside and waterproof cover on top. Retrofitting the dump trucks can be easily accomplished. Retrofitting of hauling trucks must be accomplished even for on-site transportation.

The permitting process, required training for the drivers, necessary record keeping, and liabilities incurred by the Air Force must be considered in the use of RED HORSE as a transporter of hazardous waste. Differing state requirements will be time consuming and costly to keep up with. Off-site hauling of hazardous waste provides no wartime training to RED HORSE that could not be achieved elsewhere.

Requirements Under OSHA Standard 29 CFR Part 1910.120

Hazardous waste sites are dangerous places because of the nature of the materials found there. Because of the potentially hazardous environment, protective clothing and equipment must be worn. This protective clothing may hinder both mobility and vision. Thus, the protective clothing and equipment can add to the safety and health hazards already present.

Hazardous waste site cleanup actions present a number of potential hazards. Chemicals encountered may be reactive, flammable or toxic; other substances which are radioactive or biologically active may be present on the site as well. Heavy equipment, heavy loads, and steep or slippery surfaces are only a few of the potential safety hazards at a site. To address critical concerns for the health and safety of personnel involved in hazardous waste activities, OSHA (Occupational Safety and Health Administration) promulgated Title 29 CFR 1910.120.

The OSHA regulations were created to protect the safety and health of workers who have the potential for exposure to hazardous materials during hazardous waste site cleanup operations, work activities at TSD (Treatment, Storage, and Disposal) facilities, and emergency response activities. With regard to site cleanup operations, the standard is applicable to:

- Cleanup operations on CERCLA (Superfund) sites [including IRP sites].
- Corrective actions involving cleanup operations on RCRA sites.
- Site cleanup activities mandated by local, State, or Federal governmental bodies.
- Voluntary cleanup operations on sites recognized as uncontrolled hazardous waste disposal sites by local, State, or Federal governmental bodies. (2:10-11; 33:366)

The standard requires that the employer develop and implement a safety and health program for employees involved in hazardous waste operations. It requires that a written, site-specific Safety and Health Plan be developed for each site on which the employer's personnel are involved in cleanup operations. Table 5 summarizes the safety topics to be addressed in each Safety and Health Plan.

TABLE 5

SAFETY TOPICS ADDRESSED BY OSHA REGULATIONS (32:148)

Site characterization and analysis	Informational programs
Site control	Material handling
Training of personnel	Decontamination
Medical surveillance	Emergency response
Engineering controls, work practices, personal protective equipment	Illumination
	Sanitation
Monitoring	Excavation
Contractors, subcontractors	

To insure that the health and safety plan is followed, workers are informed of potential hazards on the site and the importance of safety; and trained to utilize the safety protocols. Information about safety is essential for both workers and visitors to the site. Visitors also are trained to recognize hazards and to observe the protocols of the safety plan. In addition to the safety topics in Table 5, other important issues to be addressed in worker and supervisor training include the chemistry of hazardous materials, toxicology, industrial hygiene, and hazard evaluation (32:149).

As will be made clear by the following discussion, the employer (RED HORSE) has many responsibilities to insure the safety and health of its hazardous waste site cleanup workers. Whereas 29 CFR 1910.120 affords certain legal rights to an employee at hazardous waste site operations, it also serves as a statement of their responsibilities.

Site Characterization and Analysis. Even though most site characterization and analysis will be accomplished before and during the remedial action design prior to RED HORSE's arrival at the site, there may be times when RED HORSE is asked to mitigate a newly discovered site. Therefore, RED HORSE personnel must be trained and capable of performing site characterization and analysis. This allows the project team leader to identify specific hazards so that appropriate protective measures can be taken. The initial entry to a site must be well planned and carefully executed. Before this initial entry, as much information as possible should be gathered on:

- Hazards involved (especially Immediately Dangerous to Life and Health (IDLH) conditions).
- Location, size, accessibility, and topography of site.

- Potential pathways of dispersion.
- Emergency response capability.
- Description and expected duration of work activities on the site. (2:13)

A detailed site evaluation will allow for selection of appropriate engineering controls, work practices, and selection of personal protective equipment. OSHA requires air monitoring during the initial site entry and also an ongoing air monitoring program after site characterization has determined the site is safe for the startup of operations (33:372).

Site Control. OSHA requires that a site control program be developed for each site. It is implemented to control employee exposure on site and to prevent migration of contaminants to clean areas of the site. It must be developed during the planning stages of cleanup operations and modified as necessary as new information becomes available or due to changing site conditions. The standards require as a minimum:

- A site map.
- Site work zones.
- Use of the buddy system on site.
- Site communications (including emergency alarm procedures).
- Safe work practices or standard operating procedures.
- Identification of the nearest source of medical assistance. (33:372)

Training. OSHA requires that all employees be adequately trained in order to do their jobs safely regardless of the job. General site workers, such as laborers and equipment operators, who engage in activities having a high exposure potential are required to complete:

- 40 hours of off-site instruction.
- 3 days of on-the-job training under the direct supervision of a trained, experienced supervisor.
- 8 hours of annual refresher training. (33:373)

Employees who work only in areas which have been monitored and fully characterized, indicating that no personal protective equipment (PPE) is required and that emergencies are unlikely are required to complete:

- 24 hours of off-site instruction.
- 1 day of on-the-job training under the direct supervision of a trained, experienced supervisor.
- 8 hours of annual refresher training. (33:373)

The same requirements apply to employees who make site visits occasionally. In addition, supervisors must complete:

- The same (or equivalent) training as required for the employees they supervise.
- 8 additional hours of specialized off-site supervisory training.
- 8 hours of annual refresher training. (33:373)

Scope of Training. OSHA regulations state "employees shall not be permitted to participate in or supervise field activities until they have been trained to a level required by their job function and responsibility" (33:372). The scope of training should be such that all employees are well versed in the following:

- Names of all site safety and health personnel and alternates.
- Site hazards.
- Use of PPE.
- Safe work practices.
- Safe use of engineering controls and site equipment
- Medical surveillance requirements.
- Symptoms which may indicate overexposure to site hazards.
- Site control measures.
- Decontamination procedures.
- Provisions of the emergency response plan.
- Confined space entry procedures [these include open trenches].
- Spill containment procedures. (2:15)

OSHA requires the supervisor's additional training to cover such topics as:

- The employer's safety and health program.
- Employee training program.
- PPE program.
- Health hazard monitoring techniques.
- Spill containment program. (33:373)

Also, it is important for certified employees who begin work on an unfamiliar site to receive site-specific training sufficient to familiarize them with any unfamiliar hazards.

Medical Surveillance. The OSHA standard requires that each employer involved in cleanup activities institute a program of medical surveillance. In particular, it is required for

> All employees who are or may be exposed to hazardous substances or health hazards at or above the permissible exposure limits or, if there is no permissible exposure limit, above the published exposure levels for these substances, without regard to the use of respirators, for 30 days or more a year. (33:374)

The frequency of the examinations must meet the following schedule:

- Before assignment of new employees.
- At least annually during employment, unless the attending physician believes a longer interval (not to exceed two years) is appropriate.
- At the time reassignment to an area or job which does not require medical surveillance, if more than six months has passed since the most recent examination.
- As soon as possible after accidental overexposure or the appearance of symptoms which may be exposure-related.
- Whenever deemed necessary by the physician.
- At the time of termination, if more than six months has passed since the most recent examination. (2:16)

Guidelines as to the content of the medical examination are given in the Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities (28).

Engineering Controls, Work Practices, and Personal Protective Equipment. The standard requires that engineering controls, work practices, and personal protective equipment (PPE) be used as required to protect employees from site hazards. An example of engineering control is the use of pressurized cabs or control booths on equipment. Example work practices include wetting down dusty operations and locating employees upwind of possible hazards (33:376).

Selection of PPE must be based on site-specific conditions and updated as those conditions change or additional information is generated at the site. OSHA requires a written PPE program which must as a minimum address the following elements:

- Selection.
- Use and limitations.
- Work mission duration.
- Maintenance.
- Storage.
- Decontamination and disposal.
- Training and proper fitting.
- Donning and doffing.
- Inspection procedures.
- Limitations during temperature extremes.
- Program evaluation. (33:377)

The specific PPE requirements for employees working in "immediately dangerous to life and health" (IDLH) atmospheres is the use of positive-pressure self-contained breathing apparatus (SCBA) fitted with a full facepiece or positive-pressure air-line respirator fitted with a full facepiece and escape air supply. Also, for work in areas of skin-absorption hazards which may result in an IDLH situation, totally-encapsulating chemical-protective (TECP) suits must be used (33:376).

Monitoring. The standard requires that air monitoring be used to identify and quantify atmospheric conditions in order to determine the appropriate level of employee protection needed on the site. Direct reading instruments are to be used for initial air monitoring for the following conditions:

- IDLH conditions.
- Atmospheres containing contaminants in excess of applicable exposure limits.
- Radiation above dose levels.
- Flammable atmospheres.
- Oxygen-deficient atmospheres. (33:377)

Periodic air monitoring should be conducted on a regular basis during cleanup operations whenever there is reason to believe that an IDLH condition or flammable atmosphere may have developed, or that exposure levels have increased above applicable exposure limits since prior monitoring.

Informational Programs. The standard requires employers to develop and implement an informational program to inform employees, contractors, and subcontractors of potential chemical exposure risks associated with site operations (33:378).

Material Handling. OSHA Standard 29 CFR 1910.120 contains a number of specific rules and procedures for the handling, transportation, labeling, and disposal of drums and other containers which may contain hazardous substances and contaminated soils, liquids, and other residues. The elements of the standard are to minimize the danger involved in handling of containers which includes the use of equipment with limited sources of ignition. The general rules under the law are:

- Drums and containers used must meet minimum DOT, OSHA, and EPA regulations for the wastes they contain.
- If practical, drums and containers will be inspected to insure their integrity prior to being moved. If drums or containers are stored or stacked so that inspection is impossible, they should be moved to an accessible location for inspection prior to further handling.
- Unlabeled drums and containers will be assumed to contain hazardous substances and treated accordingly until contents are positively characterized.

- Site operations shall be organized so as to minimize the amount of drum or container movement required.
- All employees exposed to a transfer operation shall be warned of potential hazards associated with contents of any drums or containers involved.
- DOT specified salvage drums or containers and suitable sorbent materials shall be available in areas where spills may occur.
- Where major spills are possible, a spill containment program shall be implemented as part of the employer's safety and health plan. The spill containment program shall allow for the containment and isolation of the entire volume being transferred.
- Drums and containers that can't be moved without rupture or leakage will be emptied into a sound container.
- Some type of detection system (such as ground-penetrating radar) shall be used to estimate the location and depth of buried drums or containers.
- Buried drums shall be excavated carefully to prevent rupture.
- Suitable fire extinguishing equipment will be kept on hand and ready for use. (2:143)

Decontamination. The standard requires the development and implementation of decontamination procedures before any employees or equipment may enter areas on site where potential for exposure to hazardous substances exists. All employees leaving a contaminated area shall be appropriately decontaminated; all PPE and equipment used in a contaminated area must be properly decontaminated or else disposed of in compliance with the hazardous waste management requirements of RCRA (Resource Conservation and Recovery Act) (2:19).

Emergency Response. The standard requires an emergency response plan be developed and implemented prior to commencement of hazardous waste operations. It must be made available in writing to all employees. The standard requires that the emergency response plan address each of the following topics:

- Pre-emergency planning.
- Personnel roles, lines of authority, training, and communications for emergencies.
- Emergency recognition and prevention.
- Safe distances and places of refuge.

- Site security and control.
- Site topography, layout, and prevailing weather conditions.
- Procedures for reporting emergency incidents to local, State, and Federal agencies.
- Evacuation routes and procedures.
- Emergency decontamination procedures.
- Emergency medical treatment and first aid.
- Emergency alerting and response procedures.
- Critique of response and follow-up.
- Periodic plan review and amendment.
- PPE and emergency equipment for emergency response.
- Compatibility with the disaster, fire, and emergency response plans of local, State, and Federal agencies. (33:381)

Employers may be exempt from the plan if they intend to evacuate employees from the site in case of emergency and do not intend to assist in emergency response. If this is the case, then they must have an emergency evacuation plan (33:381).

Illumination. The standard requires that all site areas have adequate lighting. It gives minimum illumination intensities in foot-candles for general site areas, excavation and waste areas, and indoor warehouse, shop, toilet, and office areas.

Sanitation. Minimum requirements for sanitation pertaining to water supplies, toilet facilities, washing facilities, and related concerns at hazardous waste cleanup sites are also mandated by 29 CFR 1910.120 (33:381-382).

Excavation. The standard requires site excavations created during initial site preparations or during hazardous waste operations to be shored or sloped as appropriate to prevent accidental collapse in accordance with subpart P of 29 CFR part 1926 (33:369).

Contractors, Subcontractors. The standard requires an employer who retains contractors or subcontractors for work at hazardous waste operations to inform those persons or their representatives of the site emergency response procedures and any potential fire, explosion, health, safety or other hazards of that hazardous waste operation that have been identified by the employer, including those identified in the employer's information program. The written safety and health program shall be made available to any contractor involved, to OSHA personnel, and to personnel of other Federal, State, or local agencies with regulatory authority over the site (33:369).

Chemical Listing. Table 6 is a by-chemical listing of the NIOSH/OSHA exposure limits, IDLH limits, personal protection requirements, and respirator selection recommendations for the ten most common organic chemicals which have been detected in soils at USAF IRP sites (as previously shown in Figure 3). The following designations apply to Table 6:

- C -- Ceiling recommended exposure limit.
- Ca -- Any substance that NIOSH considers to be an occupational carcinogen.
- Clothing -- Wear appropriate equipment to prevent:
  - Repeat -- Repeated or prolonged skin contact.
  - Any poss -- Any possibility of skin contact.
- Goggles -- Wear eye protection to prevent:
  - Reason prob -- Reasonable probability of eye contact.
  - Any poss -- Any possibility of eye contact.
- CCRFOV -- Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s).
- CCROV -- Any chemical cartridge with organic vapor cartridge(s).
- CCROVDM -- Any chemical cartridge respirator with organic vapor cartridge(s) in combination with a dust and mist filter.
- GMFOV -- Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister.
- GMFOVHie -- Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister having a high-efficiency particulate filter.
- PAPROV -- Any powered, air-purifying respirator with organic vapor cartridge(s).
- PAPROVDM -- any powered, air-purifying respirator with organic vapor cartridge(s) in combination with a dust and mist filter.

- SA:CF -- Any supplied-air respirator operated in continuous-flow mode.
- SAF:PD,PP -- Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.
- SCBA -- Any self-contained breathing apparatus.
- SCBAE -- Any appropriate escape-type, self-contained breathing apparatus.
- SCBAF -- Any self-contained breathing apparatus with a full facepiece.
- SCBAF:PD,PP -- Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.
- ∀ -- At any detectable concentration. (41)

While the NIOSH (National Institute for Occupational Safety and Health) requirements are not legally enforceable, they are recognized and used by OSHA as standards when an OSHA requirement is not readily available (36). If RED HORSE will be employed at IRP sites, it is only prudent for them to prepare for these conditions. Information concerning limits and personal protective equipment has been taken from the NIOSH Pocket Guide To Chemical Hazards (41).

Requirements Under 40 CFR Part 300

40 CFR Part 300 is the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Its purpose is

> to provide the organizational structure and procedures for preparing for and responding to discharges of oil and releases of hazardous substances, pollutants, and contaminants. (10:5)

The standard promulgates the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). Subpart E of the standard covers hazardous substance response. It places the responsibility and authority concerning response on the lead agency.

TABLE 6.
CHEMICAL LISTING (adapted from 41)

Chemical Substance	Maximum Values Detected	Exposure Limits	IDLH Limits	Personal Protection	Recommendations for Respirator Selection
Petroleum Hydrocarbons	360000 mg/kg	NIOSH 350 ppm/ OSHA 400 ppm	10000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH 850 ppm: SCBA/SA 2125 ppm: SA:CF 4250 ppm: SCBAF/SAF 10,000 ppm: SAF:PD,PP Escape: GMFOV/SCBAE
Toluene	104000 mg/kg	NIOSH/OSHA 100 ppm	2000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH/OSHA 1000 ppm:CCROV/SCBA 2000 ppm:SCBAF/GMFOV Escape:GMFOV/SCBAE
Ethylbenzene	790 mg/kg	NIOSH/OSHA 100 ppm	2000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH/OSHA 1000 ppm:SCBA/CCROV 2000 ppm:GMFOV/SCBAF Escape:GMFOV/SCBAE
Xylenes	17600 mg/kg	NIOSH/OSHA 100 ppm	1000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH/OSHA 1000 ppm:CCROV/SCBA Escape:GMFOV/SCBAE
Trichloroethylene	6800 mg/kg	NIOSH (Ca) 25 ppm/ OSHA 50 ppm	Ca 1000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH V:SCBAF:PD,PP Escape: GMFOV/SCBAE
Phenolics	580 mg/kg	NIOSH/OSHA 5 ppm	250 ppm	Clothing:Any poss Goggles:Any poss	NIOSH/OSHA 50 ppm:CCROVDM/SCBA 125 ppm:SA:CF/PAPROVDM 250 ppm:SCBAF/GMFOVHie Escape:GMFOVHie/SCBAE
Benzene	890 mg/kg	NIOSH (Ca) 0.1 ppm/ OSHA 1 ppm	Ca 3000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH V:SCBAF:PD,PP Escape:GMFOV/SCBAE
1,2-Dichlorobenzene	480 mg/kg	NIOSH/OSHA C 50 ppm	1000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH/OSHA 1000 ppm:PAPROV/CCRPOV Escape:GMFOV/SCBAE
1,4-Dichlorobenzene	480 mg/kg	NIOSH (Ca) OSHA 75 ppm	Ca 1000 ppm	Clothing:Repeat Goggles:Reason prob	NIOSH V:SCBAF:PD,PP Escape:GMFOV/SCBAE

It is assumed that when using RED HORSE for hazardous waste site cleanups, the host Air Force installation will assume the responsibility of lead agency and RED HORSE will assume the responsibility of contractor. As such, it is the responsibility of the lead agency to determine the limitations on response, provide entry and access, secure financing for the project, secure any required permits, perform health assessments, identify applicable or relevant and appropriate requirements (ARARs) governing the level of cleanup, and provide project oversight (10:44-47). It is assumed for the purpose of this study that the lead agency will have conducted remedial investigation/feasibility study and selection of remedy prior to selection of RED HORSE as a contractor. It is anticipated that chemical and analytical testing and sampling procedures conducted for the purpose of determining whether cleanup action levels have been achieved will be conducted by a subcontractor independent of RED HORSE and supervised by the host installation. However, RED HORSE is still responsible for having a knowledge of chemical, site, and action specific ARARs as well as a knowledge of environmental field sampling requirements.

A review of the standard found no other information constraining the use of RED HORSE as the contractor.

Requirements Under Title 48 CFR-Federal Acquisition Regulations System

A review of the Federal Acquisition Regulations (FARs) found no information precluding the use of RED HORSE in Air Force environmental cleanups or response actions.

Requirements Under Department of Defense and Air Force Regulations

All peacetime projects performed by RED HORSE are considered to be training projects. Any peacetime project must be inaccordance with DODD 1135.2, AFR 86-1, and AFR 93-9. The restrictions associated with these regulations were discussed in the Requirements of RED HORSE Training Projects section of Chapter IV.

Findings

An off-site hazardous waste transporter is required to obtain an EPA ID number, insurance coverage, appropriate equipment (e.g. lined trucks and placards) and comply with manifest and record keeping requirements. The transporter is required to take immediate action in the event of a discharge. The transporter is responsible for cleaning up any discharge or release. RED HORSE does not currently meet these requirements.

The driver is required under RCRA to take immediate action in the event of a discharge during transportation. Drivers must be specifically trained and capable of making a first response in the event of an incident. RED HORSE personnel do not presently have the required training.

The lack of training, proper equipment, and licensing requirements prevent RED HORSE from being able to transport hazardous wastes off-site. These constraints can be overcome but will require significant time and resources. State license and training requirements will also need to be addressed.

OSHA regulations clearly require that anyone entering an uncontrolled hazardous waste site area (which includes all IRP sites) be trained as discussed above. The intent of the OSHA regulation is to assure worker safety by requiring workers are informed of potential hazards and proper procedures. This training is not part of RED HORSE's current program.

Based on this lack of training, RED HORSE at present can not perform any uncontrolled hazardous waste site work. However, this alone as a constraint can be overcome with training. It must be remembered, however, that this training does not guarantee the technical competence, management awareness and control, and knowledge required for safely working on hazardous waste sites.

The OSHA regulations were discussed at length to provide a clear understanding of what compliance with these regulations involves. Compliance with OSHA regulations can be a difficult, expensive, and time consuming process. Each of the safety topics shown in Table 5 must be fully addressed. The in-depth discussion was intended to show that there is much more to meeting the requirements than simply sitting in required classes. For instance, having employees attend a 24 hour or 40 hour training course is not sufficient. The employee must understand and be able to apply the training. Also, the failure to meet OSHA training requirements is the primary reason RED HORSE can not currently perform any work on uncontrolled hazardous waste sites.

As the host base installation will have already chosen the technology for the IRP site cleanup and coordinated with the appropriate regulatory agencies, no specific constraints under the NCP precluding the use of RED HORSE were identified.

Air Force and DOD regulations only require that environmental remediation projects meet the same requirements that apply to any other RED HORSE project.

VI. Analysis and Conclusions

Overview

This chapter synthesizes the findings of this research. The boundaries and radius of influence of each constraint are discussed. Constraints are then matched against the technologies. The findings are discussed and recommendations are made for further study.

Constraint 1

The primary remediation requirement facing the Air Force is remediation of sites contaminated by VOCs. VOCs were found to be the most frequently occurring class of pollutants. VOCs were also found to account for a major portion of the risks associated with the sites posing the greatest risks.

Based on this finding, a technology must be capable of remediating sites contaminated with VOCs. Technologies which are innovative, emerging or not applicable are all considered to be incompatible technologies.

This constraint is the first constraint (C-1) shown in the following tables. Compatible technologies are indicated by the letter "C" in the first column. Incompatible technologies are indicated with the letter "I".

Constraint 2

The RED HORSE mission during peacetime is to train and be prepared to perform its wartime duties. Training during peacetime should provide opportunities to utilize and enhance a variety of skills. Technologies should provide an opportunity to perform activities similar to those required by wartime functions.

A technology must offer skill training to supplement the engineering capabilities of RED HORSE as listed in appendix B. This includes engineering design, construction management, and operation of heavy equipment. Equipment required by the technology must be owned by RED HORSE, the base, or be available by local rental (excluding both monitoring equipment and personal protective equipment that are considered under constraint 3). Operation of the equipment must also enhance wartime capabilities and not just provide irrelevant machine operating time.

Limitations on project dollar amount, interference with private enterprise, and the consequences of prematurely pulling off a project are not considered. The variety of site sizes and base locations vary across the Air Force and would affect the first two factors. The risk of prematurely leaving a project is present with any RED HORSE project. Therefore, these factors would be evaluated by the host installation before submitting the project to RED HORSE.

Technologies are classified using the following criteria:

1. RED HORSE has the ability to perform a basic design of a specified technology and construct or install from start to finish.
2. RED HORSE is capable of installing a predesigned or packaged system.
3. Technology is beyond the capability of RED HORSE.

These rating are shown under the C-2a column in the following tables.

Technologies are also rated based on their likelihood of providing RED HORSE with desirable training activities. The technologies are rated as follows:

1. Provide a high level of desirable and diverse training opportunities.

2. Provide a moderate level of desirable training opportunities, or limited diversity.

3. Provide little or no desirable or mission related training opportunities.

These ratings are shown in the third column of the tables under C-2b.

Constraint 3

All work performed at hazardous waste sites must be accomplished within all applicable regulations. These regulations include HMTA, RCRA, OSHA, NCP and FAR. This constraint does not cover choice of technologies for use at a site. State regulations and local requirements are not considered.

The legal constraints are broken into the following categories:

1. No legal requirements preclude use of RED HORSE.

2. No Legal constraints that require significant efforts to overcome (for example, OSHA training requirements and requirements for monitoring and personal protective equipment).

3. Legal constraints requiring extensive and extended efforts to overcome (such as a RCRA part B permit).

These ratings are shown in the fourth column of the tables under the heading C-3.

Results

Each of the technologies was compared to the three constraints. The constraints concerning RED HORSE capabilities and training benefits were discussed with a RED HORSE engineer to insure proper ranking of each technology.

The results of this study are shown in Tables 7 - 14. The findings are discussed in the following section.

Discussion of Results

The findings of this research indicate that there are 125 technologies compatible with remediation of VOC contaminated sites. Many of these technologies would be used as part of a treatment series and are not stand alone technologies.

The second constraint has two parts. The first part deals with RED HORSE's ability to design or implement the technology. The findings of this research indicate there are up to 43 compatible technologies that RED HORSE may be able to design and install. There are 44 compatible technologies that RED HORSE can possibly install if available as a packaged system. There are at least 38 technologies that are probably completely beyond the capabilities of RED HORSE.
The second part of this constraint addresses the level of training benefits RED HORSE would receive from the remedial action. This study found that up to 30 of the compatible technologies would provide a high level of training benefits and up to 39 would provide moderate levels of training benefits to RED HORSE. Technologies offering more diverse training opportunities were given higher ratings. Less diverse activities that offered RED HORSE opportunities to engage in well

drilling were also given high ratings. The higher rating was warranted because RED HORSE does not typically get sufficient opportunities to perform well drilling activities.

TABLE 7

SURFACE WATER STRATEGIES

TECHNOLOGY	C-1	C-2a	C-2b	C-3
CONTAINMENT				
Cofferdams	C	1	1	2
Floating Cover	C	1-2	3	2
Silt Curtain & Booms	C	1	3	2
DIVERSION				
Dikes & Berms	C	1	1	2
Terraces & Benches	C	1	1	2
Levees	C	1	1	2
Floodwalls	C	1	1	2
COLLECTION				
Ditches, Trenches, & Diversion	C	1	1	2
Chutes & Downpipes	C	1	1	2
Seepage Basins & Ponds	C	1	1	2

Legend:
C-1. Constraint 1.
C. Technology is compatible with remediation of VOCs
I. Technology is emerging, innovative, or not applicable to VOCs.

C-2a. Constraint 2a.
1. RED HORSE is capable of designing and building.
2. RED HORSE is capable of installing predesigned/package system.
3. Beyond RED HORSE capability.

C-2b. Constraint 2b.
1. Potential training benefits are high.
2. Moderate to low potential training benefits.
3. Very little or no potential training benefits.

C-3. Constraint 3.
1. No legal requirements preclude use of RED HORSE.
2. No legal constraints that require significant efforts to overcome.
3. Significant legal constraints on use of RED HORSE.

TABLE S

GROUNDWATER STRATEGIES

TECHNOLOGY	C-1	C-2a	C-2b	C-3
CONTAINMENT				
Slurry Walls	C	1	2	2
Soil/Cement-Bentonite	C	1	2	2
Vibrating Beam	C	2	2	2
Sheet Piling	C	1	1	2
Grout Injection	C	1	1	2
Grout Curtain	C	1	1	2
Bottom Sealing	I			
Slurry Floor	C	3	3	2
Block Displacement	C	3	3	2
Controlled Pumping	C	1	1	2
COLLECTION				
Pumping				
Well Points	C	1	1	2
Withdrawal Wells	C	1	1	2
Deep Wells	C	3	3	2
Drains				
Pipe Drains	C	1	1	2
Gravel Drains	C	1	1	2
Pure Compound Recovery				
Direct Pumping	C	1	2	2
Mechanical Skimming	C	1	1	2
Oil/Water Separator	C	2	1	2
Interceptor Trench	C	1	1	2
IN-SITU TREATMENT				
Bioreclamation/Subsurface Injection	C	2	1	2
Permeable Barriers	C	1	1	2

TABLE 9

AQUEOUS WASTE STRATEGIES

TECHNOLOGY	C-1	C-2a	C-2b	C-3
TREATMENT				
Physical Treatment				
Flocculation	I			
Sedimentation	C	2	2	2
Filtration	C	2	2	2
Skimming	C	1	1	2
Dissolved Air Floatation	C	3	3	2
Oil/Water Separator	C	2	1	2
Air Stripping	C	2	3	2
Steam Stripping	C	2	3	2
Distillation	C	2	2-3	2
Evaporation	C	2	1-3	2
Ion Exchange	C	3	3	2
Carbon Adsorption	C	2	3	2
Resin Adsorption	C	3	3	2
Biosorption	C	3	3	2
Reverse Osmosis	C	2	2	2
Ultrafiltration	C	2	2	2
Solvent Extraction	C	3	3	2
Freeze-Crystallization	C	3	3	2
Chemical Treatment				
Precipitation	C	1	3	2
Oxidation	C	3	3	2
Reduction	I			
Neutralization	I			
Hydrolysis	C	3	3	2
Electrolysis	I	3	3	
UV Photolysis	C	3	3	2
Ozonation	C	3	3	2
Wet Air Oxidation	C	3	3	2
Super Critical Wet Air Oxidation	I			
Dehalogenation	C	3	3	2
Biological Treatment				
Lagoons				
Aerated Lagoon	C	1	2	2
Facultative Lagoon	C	1	2	2

TABLE 9 (CONT)

AQUEOUS WASTE STRATEGIES

TECHNOLOGY	C-1	C-2a	C-2b	C-3
Stabilization Pond	C	2	2	2
Algal Pond	C	2	2	2
Suspended Growth Processes				
Activated Sludge	C	2	2	2
Sequencing Batch Reactor	C	2	3	2
Oxidation Ditch	C	1	2	2
Powdered Activated Carbon Treatment	C	2	3	2
Attached Growth Processes				
Trickling Filter	C	2	2	2
Rotating Biological Contactor	C	2	3	2
Aerated Biofilter	C	2	3	2
Anaerobic Biofilter	C	2	3	2
Fluidized Bed Reactor	C	2	3	2
Land Treatment				
Overland Flow	C	1	2	2
Spray Irrigation	I			
Infiltration Basin	C	1	2	2
Thermal Destruction				
Liquid Injector Incineration	C	3	3	
Pyrolysis	C	3	3	
Plasma Arc Pyrolysis	I	3	3	
Industrial Boilers	C	3	3	
Cement & Lime Kilns	C	3	3	
DISPOSAL				
Discharge to Surface Water	C	1	2	2
Discharge to Sewer System/POTW	C	1	2	2
Land Application	C	1	2	2
Deep Well Injection	C	3	3	2
Surface Impoundment	I			
RCRA TSDF	C	3	3	3

TABLE 10

SLUDGE/SEDIMENT STRATEGIES

TECHNOLOGY	C-1	C-2a	C-2b	C-3
COLLECTION				
Dredging	C	2	2	2
Vacuum Loading	C	3	3	2
IN-SITU TREATMENT				
Drying	I			
Chemical Fixation	C	2	2	2
EX-SITU TREATMENT				
Dewatering				
Gravity Thickening	C	2	3	
Air Flotation Thickening	C	2	3	
Vacuum Filtration	C	3	3	
Filter Press	C	2	3	
Centrifugation	C	2	3	
Carver-Greenfield Process	I			
STORAGE				
Lagoons	I			
Surface Impoundments	I			
DISPOSAL				
POTW	C	1	2	1
RCRA TSDF	C	3	3	3
Off-Site Landfill	I			
On-Site Landfill	I			
Surface Impoundment	I			

TABLE 11

SOIL STRATEGIES

TECHNOLOGY	C-1	C-2a	C-2b	C-3
IN-SITU TREATMENT				
Soil Flushing	C	2	2	2
Vacuum Extraction	C	2	2	2
Chemical Fixation	C	2	2	2
Vitrification	I			
Land Farming	C	2	2	2
COLLECTION				
Excavation	C	1	1	2
Solids Handling				
Screening	I			
Scalping	I			
EX-SITU TREATMENT				
Soil Washing	C	2	2	2
Thermal Desorption	C	3	3	
Chemical Fixation	C	2	2	2
Biological Treatment				
Slurry Reactor	C	3	3	
Land Farming	C	2	2	2
Composting	I			
Solvent Extraction	C	3	3	
Thermal Destruction				
Rotary Kiln Incinerator	C	3	3	
Fluidized Bed Incinerator	C	3	3	
Circulating Bed Combustor	C	3	3	
Multiple Hearth Incinerator	C	3	3	
Molten Salt Combustion	C	3	3	
Pyrolysis	C	3	3	
Plasma Arc Pyrolysis	C	3	3	
Infrared Incineration	C	3	3	
Industrial Boilers	C	3	3	
Cement & Lime Kilns	C	3	3	
STORAGE				
Waste Piles	I			
DISPOSAL				
Off-Site Landfill	I			
On-Site Landfill	I			
Surface Impoundments	I			
Mines & Salt Domes	I			
Storage Mounds	I			

TABLE 12

GAS CONTROL STRATEGIES

TECHNOLOGY	C-1	C-2a	C-2b	C-3
COLLECTION				
Passive Vents	C	1	2	
Gas Extraction Wells	C	1	2	
Air Injection Wells	C	2	2	
Air/Water Separator	C	2	2	
TREATMENT				
Gas Phase Carbon Adsorption	C	2	2-3	2
Catalytic Oxidation	C	2	2-3	2
Vapor Combustion	C	2-3	2-3	2
Flaring	C	2	3	2

TABLE 13

DRUM & DEBRIS CONTROL ACTIONS

TECHNOLOGY	C-1	C-2a	C-2b	C-3
DRUM REMOVAL	C	1	3	2
DEBRIS DECONTAMINATION	C	2	3	2

TABLE 14

GENERAL SITE CONTROLS

TECHNOLOGY	C-1	C-2a	C-2b	C-3
GRADING	C	1	1	2
DUST CONTROL	C	1	1	2
CAPPING				
Soil	C	1	1	2
Asphalt	C	1	1	2
Concrete	C	1	1	2
REVEGETATION	C	1	2	2

A comparison of RED HORSE's capability to design or install technologies compatible with VOC remediation and potential training benefits is shown in Table 15 (Summary Comparison of Capabilities and Benefits).

The legal constraint governing environmental remediation projects was the constraint that eliminated use of RED HORSE the m st often. If the site is an uncontrolled hazardous waste site, then RED HORSE personnel do not have the required training to work on or enter the site. This is an OSHA requirement. This training constraint can be overcome by providing RED HORSE personnel with the required OSHA training. RED HORSE is also precluded from working on uncontrolled hazardous waste sites due to not having the monitoring equipment

TABLE 15

SUMMARY COMPARISON OF CAPABILITIES AND BENEFITS

CAPABILITIES RANKING (C-2a)	POTENTIAL LEVEL OF TRAINING BENEFITS (C-2b)		
	High	Moderate to Low	Very low or None
Design and Build	26	15	4
Install Packaged System	4	25	21
Beyond Capability	0	1	38

required by OSHA. This constraint can be overcome by equipment purchase

If the site is a controlled hazardous waste site, then RED HORSE may be able to work on the site. An example where RED HORSE could be used is following chemical treatment to fixate the waste. RED HORSE could then install a cap to prevent rainwater from percolating into the site and causing the fixated waste to leach into groundwater.

Advantages to Using RED HORSE

There are a number of potential advantages that the Air Force would receive if RED HORSE were supplied with the required training and monitoring equipment to enable their use in performing remediation projects. Depending on the cost of providing RED HORSE with the required monitoring equipment and training, use of RED HORSE may be economically desirable. The Air Force would receive desirable hazardous waste site remediation and RED HORSE would receive desirable training opportunities. This is especially true for RED HORSE's under utilized well drilling team .

Another benefit to the Air Force is the availability of another contracting option for a base. RED HORSE can be mobilized and arrive at a site rather quickly as opposed to sometimes long, difficult, and time consuming contract negotiations.

The advantage of using RED HORSE to perform a site remediation is that quite often, remediation is a trial and error procedure. Use of RED HORSE may provide greater flexibility than is possible with a contractor, even when innovative contracting techniques are used.

The use of RED HORSE to perform remediations may provide the Air Force with a positive public relations opportunity. The Air Force would be showing a desire to speed up the remediation process.

Drawbacks to Using RED HORSE

There are a number of drawbacks to using RED HORSE to perform environmental remediations. RED HORSE personnel do not have the training or knowledge required by OSHA regulations. Even if this training is provided, a strong and convincing argument can be made that OSHA training alone is insufficient. This is especially true for the engineers and managers, who are not professionally trained in the area of environmental remediation. The current personnel also lack the correct monitoring equipment and technical understanding associated with its use.

Using RED HORSE would increase the risks and liabilities of the Air Force. Environmental regulations are voluminous, complex, and occasionally conflicting. However, these are not sufficient reasons to fail to fully obey each and every legal regulation. This is an important consideration, as even a simple clerical error could cost the Air Force tens of thousands of dollars a day in fines. Failure to fully comply could also result in criminal charges against individual RED HORSE members, the entire unit, and the Air Force.

RED HORSE members would potentially be exposed to greater health risks because uncontrolled hazardous waste sites typically present hazards not associated with controlled hazardous or nonhazardous waste sites. These risks include chemical exposure, encumbrance with personal protection equipment, and increased susceptibility to heat exhaustion.

Summary

The findings of this research effort indicate that RED HORSE can not currently be used to perform any of the identified technologies at uncontrolled hazardous waste sites. RED HORSE can, however, perform many of the remedial technologies identified if the site is a controlled site.

A Brief summary of the findings of this research is presented in Table 16 (Summary of Conditions on Use of RED HORSE).

The primary reason that RED HORSE can not presently be used to perform environmental remediation is that RED HORSE does not have the training or equipment required by OSHA regulations. These obstacles can be overcome by equipment purchase, providing RED HORSE personnel with the required OSHA training, and adding bio-environmental and environmental engineers to the squadron. An alternative to adding the

TABLE 16

SUMMARY OF CONDITIONS ON USE OF RED HORSE

CONDITION	FINDING
Uncontrolled site. RED HORSE training/equipment status as of today	No use possible
Controlled site. RED HORSE training/equipment status as of today	Use is possible
Uncontrolled site. RED HORSE training, monitoring, and equipment upgraded to meet OSHA requirements.	Use is possible on site
Controlled or uncontrolled site. RED HORSE training/equipment upgraded to meet HMTA requirements.	May be used as hazardous waste transporter

engineers would be to use outside contractors to provide environmental engineering expertise.

This study indicates that with appropriate training and equipment. RED HORSE can be used to perform remedial actions. Without this training, RED HORSE can only be used at controlled hazardous waste sites.

Unless provided With the proper training and equipment, RED HORSE's role in environmental remediation will be severely restricted. Few (if any) IRP sites meet the definition of a controlled hazardous waste site. Sites meeting the definition of a controlled hazardous waste site will probably be those that have already been remediated.

Before using RED HORSE to perform hazardous waste site remediation, policy makers need to consider the benefits and liabilities. Many of the training benefits associated with site remediation can be obtained by RED HORSE without exposing RED HORSE and the Air Force to the strict regulatory requirements and liabilities associated with hazardous waste site remediation.

Use of RED HORSE as an off-site transporter of hazardous waste is a decision that policy makers should weigh carefully. The driver is responsible for responding in case of an emergency. Also, the Air Force would carry all responsibility in case of an accident and receive considerable adverse publicity.

Recommendations for Further Study

The completed study took a macro view of using RED HORSE to perform environmental remediation projects. There are several narrower issues that should be investigated. These are presented below.

Many uncontrolled hazardous waste sites offer limited exposure opportunities. An economic benefit analysis should be performed to determine if providing RED HORSE with the expertise, training, and equipment required to participate in environmental remediations of uncontrolled sites is justified.

Training while wearing appropriate personal protective equipment may be less effective due to the negative distractions of the equipment. Alternatively, this training may provide positive training benefits with respect to preparation for chemical warfare operations. A study should be performed to determine and quantify the benefits or lack of benefits of training while wearing appropriate personal protective equipment.

RED HORSE has an under utilized well drilling team. The Air Force is continuously contracting for monitoring wells to "determine the horizontal and vertical extent of contamination" as required by most regulatory agencies. The feasibility of providing just the drilling team with appropriate training and equipment to work on hazardous waste sites should be examined.

Appendix A: Hazardous Waste Site Cleanup Strategies

I. Surface Water Strategies - Surface water strategies are characterized by one of the following functions: "prevention of run-on and/or interception of runoff; prevention of infiltration: control of erosion; collection and transfer of water; storage and discharge of water; and protection from flooding" (3:9.43).

A. Containment

1. Cofferdams - Cofferdams are temporary walls or enclosures for protecting an excavation. Cofferdams include earth dikes; timber cribs: double-wall cofferdams (two lines of sheetpiles tied together and the space between filled with sand); cellular cofferdams (formed of interlocking steel sheetpiles and filled with sand); single-wall cofferdams; soldier beams and horizontal wood sheeting (used where impermeability is not required); and liner-plate cofferdams (used for excavating circular shafts). (26:7.44-7.49)

2. Floating Cover - Used on a temporary basis to prevent over-topping of a hazardous waste impoundment. A one-piece synthetic liner is placed over the impoundment with perimeter anchors and floating supports. The primary design objective is to keep out rainwater; if required, gas collection is included in the cover design (3:9.50).

3. Silt Curtain & Booms - Passive synthetic barriers that float on top of water used to entrap any floating contaminants such as petroleum.

B. Diversion

1. Dikes & Berms - Dikes are compacted, lined or unlined ridges designed to divert uncontaminated surface water flow away from a waste disposal site or to retain contaminated surface water flow on-site for subsequent treatment or disposal (29:1.7-1).

2. Terraces & Benches - Terraces are embankments or combinations of embankments and channels constructed along the contour of very long or very steep slopes. Terraces can be used to intercept and divert surface flow away from a site and to control erosion by reducing slope length. In contrast, with a natural fall terrace, a berm or dike is constructed downslope to allow the water to flow into the ditch. Terraces are usually used in conjunction with other remedial measure technologies, such as basins or ditches, to complete their intended purpose. (29:1.13-1)

3. Levees - A levee is a dike or berm for confining a stream or a sea channel.

4. Floodwalls - A floodwall is much like a cofferdam, but used for holding back tidal surges or expected rising waters.

C. Collection

1. Ditches, Trenches, & Diversions - These structures are excavated ditches or swales that are usually wide, shallow, and have a gentle slope. Trenches are most commonly used to collect and transfer runoff diverted from critical areas of waste disposal sites to onsite storage, treatment, or to offsite conveyance systems (29:1.3-1).

2. Chutes & Downpipes - Chutes (also called flumes) are open channel structures. Downpipes (also called downdrains or pipe slope

drains) can be either open or closed conduit systems. Chutes and downpipes are useful for conveying heavy flows of runoff and preventing erosive damage (29:1.14-1).

3. Seepage Basins & Ponds - Seepage basins are used to induce infiltration of collected water into the ground. They have several possible functions: to dispose of treated water, to dispose of diverted water, to enhance ground water supply, to modify local ground water gradients, to flush out the unsaturated zone, and any combination of the above (29:1.12-1).

II. Ground Water Strategies. Ground water strategies generally are classified as either contaminate management, or contaminate remediation strategies. Management strategies include: plume containment, modification of either clean or contaminated groundwater flow pathways, and leachate prevention (3:9.52). Remediation strategies are those which remove or degrade contaminates.

A. Containment

1. Slurry Walls - These are subsurface, physical barriers typically constructed from cement, grout, or bentonite. Their purpose is immobilize the contaminates by reducing or restricting the horizon movement of groundwater. This is accomplished by inserting a low permeability barrier to divert the flow of groundwater around the source of contamination. A variety of methods can be used to install the barrier.

a. Soil/Cement-Bentonite - This technology is implemented by excavating a trench and filling with cement, bentonite, low permeability soil, or a mixture of these materials. The trench is typically excavated until a confining layer such as clay or bedrock is reached (29:1.8-1). Trenches may exceed 200 feet and have permeabilities in the range of 1 x 10-7 to 1 x 10-6 cm/sec (6).

b. Vibrating Beam - A slurry is injected into the ground through the bottom of an I-beam as it is slowly raised. The I-beam is inserted into the ground by using a vibrating driver-extractor (46:133). This technique is similar to the grout curtain technology and is used in soils containing primarily loose sand or gravel.

2. Sheet Piling - The purpose of this technology is to divert groundwater away from a contaminated area. This is accomplished by driving sheets of steel into the soil surrounding the contaminated area. Water may initially seep through joints between the sheet piling until the joints are clogged by fine particles. Sheet piling is normally used in clayey, sandy or silty soils (29:1.9-1).

3. Grout Injection - A special liquid (or grout) is injected into the subsurface to restrict groundwater inflow or outflow to an area. The liquid is injected into void spaces between soil particles where it solidifies. This process reduces permeability of the soil and produces an effective barrier to groundwater flow.

4. Grout Curtain - This process is similar to the grout injection process. The primary difference is that rows (or curtains) of grout are injected in a pattern (29:1.1-2). Since this strategy is considerably more expensive than grout injection, it is rarely used except as a last resort.

5. Bottom Sealing - Grout is injected into bore holes to create a horizontal barrier. This barrier prevents contaminants from migrating downward (46:133).

6. Controlled Pumping - Injection and/or extraction wells are used to contain a plume to a general area. The extraction well creates an area of draw down and causes contaminants to flow toward the extraction well. Water from the extraction well is typically treated and returned to the aquifer via recharge basins or injection wells. Injection wells can be used to modify the hydraulic gradient around the plume and prevent its migration.

B. Collection

1. Pumping - Groundwater is transported from the subsurface to the surface for a variety of reasons. The most common use of pumping is to bring contaminated groundwater to the surface for treatment. Plumes of contaminated groundwater can also be contained by pumping (see Controlled Pumping). Another purpose of pumping is to prevent aquifer contamination by lowering the water table below the zone of contamination.

a. Well Points - Water is removed from an aquifer using closely spaced wells to lower the water table. The effectiveness of this technology depend upon a number of factors including: site size, depth, transmissivity, and storativity of the aquifer (29:1.2-1).

b. Withdrawal Wells - Water is pumped from the aquifer using one or more wells. The water is brought to the surface for treatment or disposal. Drawdown associated with this technology is incidental.

c. Deep Wells - These wells extend thousands of feet below the surface. The theory is that injection of wastes into these wells will put the wastes far below any potentially usable aquifer. Drilling wastes and wastes containing low levels of hazardous compounds are typically injected.

2. Drains

a. Pipe Drains - Subsurface drains made of perforated pipe or tile placed at the bottom of trenches. The trenches are lined with gravel or coarse sand and backfilled with clay or soil. Pipe drains are used to capture leachate or intercept infiltration and prevent leachate formation.

b. Gravel Drains - These drains are simple trenches filled with gravel. The gravel provides a highly permeable channel. Subsurface liquids will follow the gravel channel as it provides the path of least resistance. These drains may also be lined with clay to prevent downward migration of the liquids.

3. Pure Compound Recovery

a. Direct Pumping - Pure products which are immiscible with groundwater will form a separate phase and can be pumped from an aquifer. Typically the pure product exits as a separate phase on the surface of the groundwater table.

b. Mechanical Skimming - Products that form a separate phase in liquid can be removed by a mechanical skimmer. Typically a skimmer sweeps the surface of the liquid and removing the very top layer.

c. Oil/Water Separator - This process takes advantage of the density difference between the two liquids. The oil phase will separate from the aqueous phase. The lighter of the two phases will float while the higher density phase sinks. Separation time and effectiveness is a function of oil droplet size and water solubility. There are several methods to improve the separation including: installing baffling, coalescing filters, and froth floatation.

d. Interceptor Trench - This is an open trench (that may be backfilled with coarse gravel for stability) or ditch installed near the top of the water table. It functions similar to an infinite line of wells and is effective at removing light, nonaqueous phase liquids like gasoline from the capillary fringe (8:717).

C. In-situ Treatment

1. Biological Degradation - Bacteria are encouraged to use organic contaminants as a food source and mineralize them. Existing bacteria are normally used but specially bred bacteria may be introduced. There are two primary types of biological degradation: aerobic and anaerobic. One major benefit to this technology is that contaminants do not require removal from the area but are destroyed in place.

2. Subsurface Chemical Injection - Various chemicals are injected into or around the area of contamination to effect a change. The change varies depending upon the desired goal. A base or chelating agent may be injected to reduce metal mobility at one site while surfactants are used to increase mobility of other contaminants.

3. Permeable Barriers. These barriers allow liquids to pass but filter out solid contaminants.

III. Aqueous Waste Strategies - the treatment of wastewater. Corbitt says "wasterwater is defined in the 'Glossary for Water and Wastewater Control Engineering' as being a 'combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with any groundwater, surface water, and storm water that may be present' " (3:6.1).

A. Treatment

1. Physical Treatment

a. Flocculation - Flocculation and coagulation are normally used in conjunction with other processes like precipitation or sedimentation. Both flocculation and coagulation result in the formation of larger particles. Flocculation involves one or more particles physically adhering together after colliding. Coagulation is similar but is based on electro-chemical forces as opposed to physical ones. In coagulation, particles are drawn together by electromagnetic forces such as ionic charges, or molecule polarity. Coagulation generally affects smaller particles than flocculation. Coagulation and flocculation usually occur simultaneously and are rarely (if ever) used as complete, stand-alone treatment process.

b. Sedimentation - A technology used to separate more dense solids from liquids. Usually a large basin or tank provides a quiescent zone where gravity causes solids to slowly settle. This technology is often used in conjunction with flocculation.

c. Filtration - This technology is used to remove suspended solids from liquid or gaseous streams. The liquid or gas phase moves through the pores of the filtration media which traps the solid particles. Particles may be trapped within or above the filtration media. Common filtration media include cloth fabrics, sand, and metal screens.

d. Skimming - The top layer material is removed from the aqueous waste. A partially submerged mechanical sweep may be used to remove floating material.

e. Dissolved Air Flotation - A technology used to remove suspended solids and separate phase liquids from another liquid. The liquid is held under pressure and saturated with air. When the pressure is released, microscopic air bubbles form. These bubbles adhere to the suspended solids or liquids. The suspended material then floats to the surface where it forms a layer of froth. The froth can be removed by mechanical skimmers, overflow weirs or other methods. The process is most effective when particle density is near that of water (23:236).

f. Oil/Water Separator - The relative insolubility of oil in water produces two separate liquid phases. These phases can be separated due to density differences. The lighter phase will slowly work its way above the heavier phase. Extremely small droplets requiring excessive amounts of time to separate can be separated faster by encouraging formation of larger droplets. This can be accomplished by incorporating advanced designs such as dissolved air floatation, coalescing filters, or corrugated plates. Emulsified oils may require heating or addition of chemical coagulants (6).

g. Air Stripping - A contaminated liquid is contacted with a gas phase causing volatile contaminants to transfer from the liquid phase to the gas phase. This process works best on contaminants having a high

Henry's constant and a high diffusivity. Air stripping is generally accomplished in either a countercurrent packed or countercurrent spray tower.

h. Steam Stripping - This technology is similar to air stripping except that steam is injected along with air. Injecting steam enables the removal of less volatile compounds (those having lower Henry's constants). Volatile compounds with boiling points less than 150 C can usually be removed with steam stripping (14:105). Steam stripping may also be used to regenerate exhausted activated-carbon.

i. Distillation - Distillation is a process of separating chemicals using liquid and vapor phase equilibrium. In a typical tray distillation tower, liquid flows countercurrent to the rising vapor. The liquid and vapor phases meet on each tray where they come into equilibrium with less volatile vapor phase components condensing while more volatile components vaporize. Distillation is usually accomplished in packed or tray columns. The process may be operated in either a batch or continuous mode.

j. Evaporation - This process is used to concentrate nonvolatile solutes contained in a volatile solvent. Evaporation is a volume reduction operation and not a treatment (6).

k. Ion Exchange - Ion exchange is a toxicity reduction technology used primarily to separate inorganic ionic compounds from aqueous waste streams. Weakly bonded "exchangeable" ions bound to an exchange resin transfer into solution while the contaminant bonds to more strongly to the resin. The technology is well suited to removal of heavy metals and radionuclides (6).

l. Carbon Adsorption - This technology uses the tendency of chemicals to adsorb or physically adhere to a solid surface. Granular or activated carbon that has a high surface area is often used as the collector solid. Contaminated water flows through the carbon matrix allowing contaminants to contact and adhere or adsorb to the carbon particles. The carbon must be replaced or regenerated once the surface area of the carbon becomes saturated. Unregenerated carbon must be properly disposed (24:253-254).

m. Resin Adsorption - Sorptive resins are capable of removing a wide range of polar and nonpolar organics. This is a viable technology for responding to short-term treatment requirements, or spills (3:9.28). The high cost associated with resin adsorption precludes frequent use of it to treat contaminated groundwaters (31:83).

n. Biosorption - the adsorption of hydrophobic organics onto microorganisms in the waste water.

o. Reverse Osmosis - Osmosis is a process where water diffuses through a membrane from an area of high concentration to one of low concentration. Reverse osmosis occurs in a similar manner except that water is forced through a selective membrane by applying pressure sufficient to overcome the osmotic pressure. Reverse osmosis acts as a molecular filter capable of removing both dissolved organics and inorganics, biological and colloidal contaminants (3:5.147).

p. Ultrafiltration - A high molecular weight polymer is introduced to wastewater to form metal-polymer complexes. Selective complexing can be achieved by varying pH and temperature. The enlarged metal-polymer complexes are passed through a cross-flow membrane system that captures the complexes and allows uncomplexed ions to pass (44:540).

q. Solvent Extraction - An immiscible extracting liquid is brought into contact with the contaminated liquid. The contaminant transfers to the extracting liquid which is then separated from the original liquid. The contaminant is then removed from the extracting liquid by another technology such as distillation. This enables reuse of the extracting solvent. This technology is also referred to as liqu'd-liquid extraction.

r. Freeze-crystallization - This is a five step process typically used to remove dissolved solids from aqueous liquids. slurries or sludges (6). The five steps include heat exchange, freezing, washing, melting and energy recovery. As the aqueous solution freezes. pure ice crystals of water are formed. This concentrates the contaminants in the remaining liquid. The ice is then removed leaving a highly concentrated solution containing the contamination. This is an effective treatment technology, but excessive energy costs prevent its use for solutions with only low-levels of contamination (6).

2. Chemical Treatment

a. Precipitation - Soluble contaminants are converted into insoluble forms that are readily removable.

b. Oxidation - Oxidation is capable of removing a variety of contaminants from wastewater. Contaminants can be converted into insoluble form, another form for continued treatment, or completely mineralized (6). The process requires that oxygen, hydrogen peroxide or other oxidizing agent be contacted with the contaminant for sufficient time to allow oxidizing reactions to take place. Oxidation may be used as a pretreatment or polishing treatment.

c. Reduction - A reducing agent is used to lower the oxidation state of a substance to reduce its toxicity. Typically the waste stream is adjusted to the desired pH prior to addition of the reducing agent (6). Many metals respond well to this type of treatment.

d. Neutralization - The purpose of neutralization is to change the pH of wastewater to a value closer to a pH of seven. Acids are used to reduce the pH of a waste water while bases are used to increase it. This technology may be used alone, as a pretreatment, or as a post treatment.

e. Hydrolysis - A chemical reaction in which an organic chemical reacts with water or a hydroxide ion (39:121) In aqueous solutions of electrolytes, the reactions of cations with water to produce a weak base or of anions to produce a weak acid (Parker:458).

f. Electrolysis - Chemical reactions are caused by introducing an electrical current to a solution. It is frequently used to separate metal salts from plating rinses (24:255).

g. UV Photolysis - Ultraviolet (UV) light is used to breakdown chemical bonds. The light excites the molecular bond and provides sufficient energy to cause a chemical reaction. Photolysis can be caused by a variety of light sources including sunlight and fluorescent light (6).

h. Ozonation - Ozone is a strong oxidizing agent capable of degrading a number of organic compounds. Oxygen or air enriched with ozone is allowed to contact the wastewater and react with constituents capable of being oxidized.

i. Wet Air Oxidation - This process oxidizes organic constituents in waster to lower molecular weight compounds or completely mineralizes them. Wastewater and air or oxygen are introduced in a chamber at temperatures up to 600 F and pressures up to 200 atmospheres. Reaction time is generally in the 30 to 120 minute range (6).

j. Super Critical Wet Air Oxidation - This process is similar to wet air oxidation except that temperatures and pressures above the critical point are used.

k. Dehalogenation - This technology involves the removal of halogens from halogenated compounds such as trichloroethylene. Halogenated compounds are generally more difficult to degrade than similar nonhalogenated compounds. Once the halogens are removed, the remaining compounds are degraded under aerobic conditions. Halogenated compounds can be often be partially dehalogenated under anaerobic conditions (1:81).

3. Biological Treatment

a. Lagoons

i. Aerated Lagoon - This is an aerobic method of treating organic compounds contained in wastewater. Wastewater is introduced to a shallow pond which is forcibly aerated. Microorganisms (such as bacteria) use the contaminants as food enabling cell division or regeneration. Some wastewaters require addition of trace nutrients to maintain sufficient numbers of microorganisms.

ii. Facultative Lagoon - These lagoons are of intermediate depth and divided into three zones. The zones are naturally occurring due to solids settling and a thermocline. The solids are anaerobically digested. Bi-products of this digestion may be soluble liquids or gases that move upward and continue being anaerobically digested. By-products from the second digestion move upward where they undergo aerobic in the top zone. Oxygen is provided to the top zone by the atmosphere.

iii. Stabilization Pond - These are deeper ponds which maintain anaerobic conditions throughout. There may be a thin layer of oxygen containing water at the very surface until a layer of grease or oil forms (23:205).

iv. Algal Pond - These are shallow ponds which require a warm, sunny climate. Photosynthesis and surface oxygen keep oxygen dissolved at all depths (3:6.113). Algae removal is required to avoid suspended solids in the effluent.

b. Suspended Growth Processes

i. Activated Sludge - Suspended microorganisms break down organic constituents in wastewater aerobically. Air or oxygen is continually added to the wastewater causing agitation and allowing the aerobic digestion to occur. The material then flows to a solids separation tank. The solids are primarily bacterial cells. Some of these cells are recirculated while the remainder receives further processing and is sent for disposal (24:246).

ii. Sequencing Batch Reactor - A sequencing batch reactor (SBR) combines biological treatment and sedimentation in a single basin (3:6.100). The tank or basin is filled with influent and mechanically mixed and aerated. Once full, mixing and aeration continue. Mixing and aeration are then stopped and matter is allowed to settle. The supernant is then drawn off as is the bottom material. Then the basin is on standby until needed again (3:6.100).

iii. Oxidation Ditch - This is an extended aeration basin. Contaminants are broken down by microorganisms aerobically. The liquid is retained and circulated until new cells formed by aerobic digestion are cannibalized at the rate of their production (3:6.102).

iv. Powdered Activated Carbon Treatment - Powdered activated carbon is added to wastewaters to remove organics and assist with clarification.

c. Attached Growth Process

i. Trickling Filter - Wastewater trickles over a structure made of synthetic material, rock, or similar material. The material is covered with a thin coating of microorganisms which use the organic material in the wastewater as food.

ii. Rotating Biological Contactor - Special discs or drums coated with microorganisms rotate through basins containing wastewater. The discs are partially submerged in the wastewater. This allow the microorganism to be exposed to both the wastewater and oxygen contained in the atmosphere.

iii. Aerated Biofilter - Contaminated water is introduced in a mixing tank and adjusted to the desired pH. Microorganisms immobilized on porous packing form a bioreactor (42). Wastewater is forced over the packing where the bacteria degrade the organic material. Air is supplied by diffusers at the base of the filter.

iv. Anaerobic Biofilters - Packing material is used to provide sites for anaerobic microorganisms. Wastewater is forced over the packing where the bacteria degrade the organic material. There is no aeration of the wastewater for this process (3:6.129-6.131).

v. Fluidized Bed Reactor - An anaerobic, up flow system that uses suspended sand to provide a site for microorganism. Wastewater is pumped upward through the sand at a sufficient rate to keep the sand in turbulence but not blow the sand out the top (3:6.131).

d. Land Treatment

i. Overland Flow - Wastewater is applied on the top section of a series of sloped and vegetated terraces (23:197). The wastewater is remediated by physical, chemical and biological processes as it works its way downward.

ii. Spray Irrigation - Wastewater is sprinkled onto a moderately or highly permeable soil that is covered with vegetation. The water is treated by a variety of process including filtration, sorption, ion exchange, microbial action, and plant uptake as it moves through the soil (23:189).

iii. Infiltration Basin - Wastewater is allowed to percolate through an area of high permeability soil and allowed to reach groundwater (23:201). A grass cover may be used to help remove suspended solids, but the area is not usually vegetated.

4. Thermal Destruction

a. Liquid Injector Incineration - A liquid or gas waste is injected through a burner inside a refractory-lined chamber. The chamber provides sufficient residence time for complete combustion of the waste (48:257).

b. Pyrolysis - Waste is incinerated using insufficient oxygen. This process is sometimes referred to as a type of thermal distillation.

c. Plasma Arc Pyrolysis - The waste is pyrolized by an electric arc. The molecules are dissociated into ions (20:78)

d. Industrial Boilers - These exist in a variety of shapes and styles. Typically the boilers are used to produce heat for drying and steam production.

e. Cement & Lime Kilns - The waste is used as a fuel replacement for oil or coal used by the kilns. Residual solids are captured in the cement.

B. Disposal

1. Discharge to Surface Water - Wastewaters containing low concentrations of contaminants are discharged into surface waters. The discharged water is usually effluent from a previous treatment step.

2. Discharge to Sewer System/POTW - Wastewater is discharged into the sanitary sewer for additional treatment. The wastewater is typically of little hazard, very dilute, and/or amenable to standard municipal sewage treatment.

3. Land Application - This is a managed treatment and disposal process. The waste is applied under controlled conditions to the

ground. Physical, chemical and biological processes remove the pollutants.

4. Deep Well Injection - This is a form of subsurface disposal. Waste is injected into underground reservoirs several thousand feet below the surface and far below groundwater level.

5. Surface Impoundment - Wastes are stored in excavated or diked areas. This is usually a temporary measure unless the impoundment is a landfill.

6. RCRA TSDF - Waste may be treated and/or stored permanently at these EPA permitted facilities.

IV. Sludge/Sediment Strategies

A. Collection

1. Dredging - Sediment excavation from the bottom of lagoons, ponds, waterways, or similar. The sediment is dislodged. lifted. transported and disposed (6).

2. Vacuum Loading - Air is expelled from a tank by a vacuum pump. This causes a vacuum to develop which sucks the sludge through a hose or pipe into the tank.

B. In-Situ Treatment

1. Drying - Moisture is removed from the sludge by a variety of methods including forced heat and ventilation.

2. Chemical fixation - An additive is injected to fixate the waste material into a solid form. The waste can be then be removed sent for disposal or left in place.

C. Ex-Situ Treatment

1. Dewatering

a. Gravity Thickening - Solids are allowed to settle and excess water is removed. This increases the solids content of the sludge.

b. Air Flotation Thickening - Air is injected to the sludge and adheres to the solids. Part of the aqueous phase can then be decanted to increase the solids content of the sludge.

c. Vacuum Filtration - Excess liquid is removed by applying a vacuum across a filter. Solids are retained by the filter while water is not.

d. Filter Press - The slurry is pumped through a sturdy filter which retains the solids while allowing the liquid to pass. The solids are effectively strained from the liquid.

e. Centrifugation - The sludge is spun in a container that allows water to pass while the solids are retained. The primary mechanism is centripetal force.

f. Carver-Greenfield Process - A "carrier" oil is added to the sludge to remove the hazardous organic material from the sludge (43). This is a type of extraction procedure.

D. Storage

1. Lagoons - Shallow ponds used to store or treat waste.

2. Surface Impoundments - Wastes are stored in excavated or diked areas. This is usually a temporary measure unless the impoundment is a landfill.

E. Disposal

1. POTW - These are municipal wastewater treatment systems. Typically these systems consist of several physical and biological processes connected in series.

2. RCRA TSDF - These facilities are permitted by EPA to treat, store and dispose of hazardous wastes. They may use any of a variety of technologies.

3. Off-Site Landfill - Material is transported to a landfill where it is buried. These landfills are specially constructed to prevent escape of any untreated leachate or gas from the site.

4. On-Site Landfill - Waste is permanently stored in a landfill at the current location.

5. Surface Impoundment - Wastes are stored in surface impoundments.

V. Soil Strategies

A. In-Situ Treatment

1. Soil Flushing - The soil is flushed with an appropriate solution to remove contaminants. The contaminants are leached out and collected in a series of subsurface drains or wells (6).

2. Vacuum Extraction - Wells are inserted into the contaminated zone. Air is pulled through the site by installing vacuum pumps at the wells. The contaminants volatilize and are extracted via the gas stream.

3. Chemical Fixation - An additive is used to fixate the waste material into a solid form. The waste can be removed and disposed or left in place.

4. Vitrification - Soils containing the waste are converted into a glass-like substance. This is accomplished by applying an intense electrical current to electrodes inserted into the soil.

5. Land Farming - Contaminated material is treated by an aerobic process in surface treatment beds. The waste is subjected to biodegradation, transformation, and immobilization (1:82-83).

B. Collection

1. Excavation - Contamination is removed by cutting, scooping or digging it up.

2. Solids Handling

a. Screening - Large, undesirable particles are removed by filtering the waste through a screen or grate.

b. Scalping - The top layers of soil are removed.

C. Ex-situ Treatment

1. Soil Washing - Soil is washed using an appropriate solution to remove contamination from the soil.

2. Thermal Desorption - Organic contaminants are driven off by applying low level heat (300 to 800 degrees F) (6).

3. Chemical Fixation - Waste material is removed and stabilized into a solid material via addition of a fixing agent.

4. Biological Treatment

a. Slurry Reactor - These operate similar to the activated sludge or aerated lagoon systems in sanitary wastewater treatment plants. The wastes are digested by microorganisms.

b. Land Farming - Contaminated material is treated by an aerobic process in surface treatment beds. The waste is subjected to biodegradation, transformation, and immobilization (1:82-83).

c. Composting - Waste is combined with straw, wood chips or other bulking agents, moistened and allowed to degrade due to the work of naturally occurring bacteria. Sufficient oxygen must be maintained in the pile by turning or forced aeration to prevent the pile from going anaerobic.

5. Solvent Extraction - Waste is mixed with a solvent that preferentially dissolves the contaminants. The solvent is then extracted and subjected to another treatment step to enable reuse of the solvent. This is a mass transfer process and does not destroy or degrade the contamination.

6. Wet Air Oxidation - Organic matter is oxidized to shorter, less complex compounds including carbon dioxide and water. Air, water and wastewater are combined in a reactor where destruction occurs at elevated temperatures and pressures (6).

7. Thermal Destruction

a. Rotary Kiln Incinerator - A refractory-lined, cylindrical kiln mounted at an incline. The kiln rotates as the waste moves through it and exposes fresh surfaces which undergo combustion with air.

b. Fluidized Bed Incinerator - The combustion area or "bed" of granular material is maintained in a turbulent or "fluidized" state by an upflow of air, feed material and waste.

c. Circulating Bed Combuster - Similar to a fluidized bed incinerator, the circulating bed combuster entrains solids in the combustion zone. A cyclone is used at the outlet of the unit to return solids back to the combustion chamber (20:74-75).

d. Multiple Hearth Incinerator - These units consist of several hearths in a refractory-lined shell. A rotating arm in the center of the shell moves the feed downward exposing the feed to hot gases. The feed then undergoes combustion (48:268)

e. Molten Salt Combustion - This is a type of fluidized bed incinerator except molten salt is used as the bed.

f. Pyrolysis - Waste is incinerated using insufficient oxygen. This process is sometimes referred to as a type of thermal distillation.

g. Plasma Arc Pyrolysis - An electric arc between electrodes causes molecules to dissociate into an ionized state. These ions are electrical conducting and exhibit a plasma like state (20:78).

h. Infrared Incineration - A series of heating elements generate infrared and near-infrared radiation to cause pyrolysis of feed material. Waste material is conveyed through a chamber on a belt while subjected to the radiation.

i. Industrial Boilers - These exist in a variety of shapes and styles. Typically the boilers are used to produce heat for drying and steam production.

j. Cement & Lime Kilns - These are typically a type of rotary kiln. Waste is used as the feed material or a supplemental feed. These kilns typically have relatively long residence times and operate at temperatures in the 3000 degree F range.

D. Storage

1. Waste Piles - Solid waste is stored in piles prior to treatment or transport to treatment or disposal sites. Semi-solid material may be contained in a surface impoundment or tank. These types of storage are usually intermediate or temporary measures.

E. Disposal

1. Off-Site Landfill - Material is transported to a landfill where it is buried. These landfills are specially constructed to prevent escape of any untreated leachate or gas from the site.

2. On-Site Landfill - Waste is permanently stored in a landfill at the current location.

3. Surface Impoundment - These are excavated or diked areas used to store both liquid and solid wastes. Storage is usually temporary unless the impoundment meets landfill design requirements.

4. Mines & Salt Domes - Abandoned mines and underground salt formations (or domes) are used to contain the waste material.

5. Storage Mounds - Waste is stored in piles or mounds.

VI. Gas Control Strategies

A. Collection

1. Passive Vents - A perforated pipe is installed to allow gases or vapors to escape. The pipe is typically surrounded by gravel to

enhance gas flow. The discharge can be directed to the atmosphere or a gas treatment system.

2. Gas Extraction Wells - An air ventilation pump is attached to a perforated pipe installed in the subsurface. The pipe is typically surrounded by gravel to enhance gas flow. As with passive venting, the discharge may be directed to the atmosphere or a gas treatment system.

3. Air Injection Wells - These wells are similar to gas extraction wells except the air is blown into the subsurface.

4. Air/Water Separator - A variety of devices are used to remove water from air. The water may be in the form of water vapor, mist, or spray. Separation may be required to prevent corrosion, or condensation.

B. Treatment

1. Gas Phase Carbon Adsorption - Contaminated gases are passed through a porous bed of activated carbon. The contamination adheres to the solid surface of the carbon. Once the bed becomes contaminated it must be replaced or regenerated.

2. Catalytic Oxidation - The wastes are passed over a catalyst that promotes destruction of the wastes by oxidation.

3. Vapor Combustion - Vapors are routed to some type of incinerator. Typically the vapor is mixed with inlet air.

4. Flaring - Vapors are vented through a pipe and burned by a simple flame. The flame may be self sustaining through combustion of the vapors or sustained by addition of natural gas or similar fuel.

VII. Drum & Debris Control Actions - Typically used as part of an emergency response action or method of source control (6).

A. Drum Removal - Drums are removed from the site and transported to a permitted treatment or storage facility.

B. Debris Decontamination - This includes actions such as excavation of debris, sampling, and removal of contamination from debris (6).

VIII. General Site Controls

A. Grading - The surface contour is modified to control runoff, infiltration and erosion. The six primary grading techniques are excavation, spreading, compaction, scarification, tracking, and contour furrowing (29:1.4-1)

B. Dust Control - Dust and vapor suppression techniques may be either temporary of permanent in nature. Covers such as plastic or mulch, foam sprays, and salts are examples of temporary dust and vapor suppression techniques (6). Permanent techniques include paving and other engineering controls.

C. Capping - Capping is a common method used to prevent migration of contaminants from a sight due to infiltration of precipitation. This is a containment technology that prevents or reduces infiltration, supports vegetation and controls erosion.

1. Soil - The site is covered by low permeability soil to prevent migration of contaminants. Typically the soil is a heavy clay. This clay cap prevents water from infiltrating into the site.

2. Asphalt - The site is covered with asphalt to prevent the migration of contaminants.

3. Concrete - Similar to other capping methods except concrete is used as the cover.

D. Revegetation - Vegetation can prevent erosion, slow and/or reduce runoff, or actually treat contaminated soil by uptake (29:1.6-1). Revegetation is typically the last phase of closing a site or landfill.

Appendix B: Required Characteristics and Capabilities of RED HORSE Squadrons

NOTE: The following is a partial reproduction of the RED HORSE Concept of Operations published by Headquarters Air Force Civil Engineering Support Agency, Tyndall AFB, FL. Only those characteristics and capabilities that may have a part in environmental cleanups are included.

Engineering Capabilities

Concrete Operations. Squadron personnel will be able to produce new concrete to meet minimum standards. Fast-setting concretes are preferred. The unit will be capable of operating a concrete mobile, concrete mixer, and concrete batch plant with related equipment to support beddown, hardening, and repair activities.

Material Testing. Squadrons will be required to determine the suitability of paved surfaces to carry aircraft traffic and to evaluate soils, concrete, and asphalt during construction to verify the quality of work. Additionally, squadrons will be capable of determining suitability of soils for alternate launch and recovery surface construction.

Quarry Operations. Squadrons will be capable of conducting quarry operations, to include explosive use, rock drilling, rock crushing, and conveyor operations. Materials generated from quarries will be used for RRR [Rapid Runway Repair] support, concrete production, paving operations, revetment erection, hardening, and drainage preparation.

<u>Water Well Drilling</u>. After locating a probable water source, squadrons must be capable of tapping that source. This includes drilling and developing a water well. Water well development will include connecting with water storage facilities, purification systems, and distribution systems. Both shallow and deep well-drilling capabilities are required.

<u>Mobile Facility Assets</u>. Squadrons will be capable of siting, erecting, installing, and operating mobile facility assets. All squadrons projected for deployment to theaters programmed for bare base systems use will maintain proficiency in that mobile facility asset. Both structures and utility systems are included. All squadrons will also maintain the capability to site, adapt, and erect pre-engineered facilities or those produced using automatic building machines.

<u>Fuel Systems</u>. Squadrons will be capable of installing, repairing, and maintaining expedient fuel systems for aircraft and vehicle support. This is accomplished under the supervision of the Liquid Fuels Systems Maintenance Technician (AFSC 54571) augmentee.

<u>Facility Hardening</u>. Squadrons will be required to perform hardening activities, ranging from berming and sandbagging, to constructing concrete barriers and revetments.

<u>Utility System Repair</u>. Squadrons must be able to expediently repair electrical, POL, water and sewage distribution systems in their theater of operations. The scope of effort includes repairs to fixed, installed system, and mobile assets, and the capability to perform work-around repairs using substitute materials. The ability to use expedient utility repair kits is also necessary.

Force Beddown. Squadrons must be able to site and erect cantonments (to include shop areas) for organic and incoming forces. Depending on the situation, facilities could range from tent cities and stick construction to rehabilitation and modification to existing facilities. Cantonment support also includes basic utility and sanitation services.

Heavy Earthwork. Many RED HORSE taskings rely on the ability to perform heavy earthwork. These tasks include such items as site preparation, road construction, airfield pavement expansion, and utility installation. Squadrons must be able to clear, contour, grade, level, and haul using common earth-moving equipment, including dozers, graders, dump trucks, excavators, and scrapers. Depending on local conditions, use of rock drills and a rock crushing and screening plant may be required.

Roads. Squadrons will be required to construct roads to support beddown actions and provide access to projects in outlying areas. Typical types of roads necessary will range from graded and soil-stabilized to crushed rock and asphalt.

Power Generation Plants. Squadrons must be able to establish basic electrical service capable of operating for extended periods. The scope of effort includes establishing, operating, maintaining, and repairing multigenerator plants and the ensuing tasks of refueling, phasing, and load balancing.

Command and Control. Squadrons must be capable of establishing and providing adequate command and control, regardless of type and degree of tasking. Command and control capabilities must be provided for the following types of situations: full-squadron deployment to one location, full-squadron deployment with phased arrival to one location, squadron deployment to multiple locations, in-transit operations during deployment, and work party and convoy operations. Also included as part of command and control is the ability to interface with the survival recovery center and damage control center at a deployed location and to establish a field command post at a remote location.

Engineering Design. Squadrons will be capable of completing multi-engineering discipline designs for basic beddown projects, such as airfield pavement expansion, pre-engineered facility erection, utility system installation and revetment construction.

Unit Characteristics

Disaster Preparedness. RED HORSE squadrons must maintain an effective disaster preparedness capability to successfully survive in today's wartime environment. The ability to endure a chemical environment is essential, as is the ability to operate while such agents are present. Operation must include the more critical wartime tasks, such as RRR and critical utility repair, and disaster preparedness actions, such as decontamination, chemical identification, agent monitoring, and shelter management.

Medical Support. The potential for operating in remote or austere locations raises the need for adequate, timely medical support to prevent the spread of contagious diseases and to attend to battle casualties. Additionally, many of the tasks for which RED HORSE is charged to perform are hazardous, e.g., RRR operations, demolition, heavy equipment operations, etc., which increases the possibility of injury. Furthermore, first aid/buddy care and field sanitation programs must be strongly established within each squadron.

Firefighting. The ability to combat fires in a wartime or contingency environment is an inherent requirement of a military unit to protect personnel and reduce damage to equipment and materials. RED HORSE squadrons must have the capability to contain or hinder the spread of fires through first aid firefighting and to assist trained firefighters in protecting RED HORSE resources.

Explosive Ordnance Reconnaissance. The potential exists for having large quantities of unexploded ordnance, area-denial bomblets, and antipersonnel munitions spread throughout an air base after an attack. This potential poses serious problems for base recovery efforts and continued beddown activities. Until these munitions are cleared, engineering efforts are constrained, and personnel will be hesitant to pursue their assigned taskings. RED HORSE personnel must be able to recognize, identify, describe, and understand the hazards of unexploded ordnance and know the actions to take when such items are discovered.

Vehicle Maintenance. Organic vehicle maintenance support enables RED HORSE squadrons to operate in the field independent of normal base operating support. RED HORSE Vehicle Maintenance specialists maintain the entire RED HORSE vehicle and equipment fleet. They are equipped and trained to perform maintenance ranging from normal preventive work to intermediate level repair.

Flexibility. Wartime and contingency situations are fluid. and the exact occurrences or degree of severity of damage cannot be precisely determined. To maximize the performance and capabilities of a RED HORSE squadron, an inherent flexibility must be established, centered on mission requirements and responsiveness. Units must rapidly adapt to changing conditions and provide that extra internal "reserve" of effort required to complete wartime taskings under pressure. A comprehensive, multi-skilling program will provide this flexibility. In a wartime situation, RED HORSE personnel must be capable of performing diverse tasks competently and quickly. The program must permit all AFSCs from a particular Air Force Specialty (AFS) to be trained in wartime tasks associated with that specialty. Additionally, AFSCs with a basic trade similarity must be trained to assist in tasks that cross AFS lines. This is necessary so the squadron has an operational redundancy to compensate for force attrition and to ensure specific individual AFSCs are not overtaxed at a critical moment.

Contracting. To provide the added flexibility for material support at the initial stages of employment, particularly at locations with little or no initial USAF presence, an organic contracting capability and associated financial/disbursing support must be established within RED HORSE squadrons. Not only will this capability improve material response time, but it will also permit purchase of unique, local supplies and materials not readily available in the standard USAF base supply system. This internal contracting capability is especially critical for supporting overseas utility and mechanical systems where US-made parts and equipment are not compatible.

Additionally, this provides the ability to rent or lease unique vehicle support. This support could augment RED HORSE efforts for heavy workload periods and critical, time-sensitive projects.

Mobility. The urgency and quantity of near-term engineering requirements in wartime and contingency scenarios dictate that mobility of RED HORSE squadrons be a primary concern. The units must be able to mobilize and embark quickly. reconstitute easily, and be effective immediately upon arrival at their employment locations. This mobility requirement must run throughout the entire organization. form the full squadron down to the smallest deployable echelon. The squadrons must be able to plan and execute movement through any primary mode of travel. be it air, land, or sea. If necessary to meet transportation flow opportunities or unique mission requirements, the squadrons must also be able to mobilize and move by sequential echelons.

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Vita

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13. ABSTRACT *(Maximum 200 words)* There are more than 4,000 Air Force (AF) sites requiring restoration due to hazardous waste contamination. The AF goal is to completely restore all sites by 2000. One method of achieving this ambitious goal is to use in-house capabilities. This study examinated the potential use of RED HORSE capabilities and training activities to assist with cleanup of contaminated sites. RED HORSE capabilities and training requirements were compared to the primary cleanup needs of the AF. One finding of this study suggests cleanup of sites contaminated by volatile organic chemicals (VOCs) is the primary need of the AF. The findings also indicate that RED HORSE can not perform remediation work on uncontrolled hazardous waste sites due to a lack of training and protective equipment required by OSHA regulations. This study suggests that if RED HORSE was provided with the required training and equipment, up to 30 technologies are within RED HORSE capabilities and offer high training benefits, and up to 39 would provide moderate or low training benefits.

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